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## ECONOMIC VAPORIZATION OF WATER AND EXPANSION OF STEAM.

*Analysis of Mr. Lavington E. Fletcher's experiments at Dalkeith, Scotland, on the engine and boilers of the paper mill belonging to the Messrs. Craig.*


By Chief Engineer ISHERWOOD, U. S. Navy.


The purpose for which the experiments herein analyzed were made, was to ascertain the economic efficiency of a water-tube boiler patented by the Messrs. Sinclair, of the Albion Boiler Works, Leith, and of an engine constructed by the Messrs. Bertram, of Leith Walk Foundry, Edinburgh. These experiments were conducted by Mr. Lavington E. Fletcher, the Chief Engineer of the Manchester Steam Users' Association, from whose report, on p. 129 of *The Engineer*, of Aug. 24th, 1877, the data are taken. Only the *observed* data have been taken; none of his calculations or deductions have been used, but in their place entirely different ones have been substituted, so that he is responsible for nothing in this paper except the accuracy of the quantities obtained by direct measure, weight or count.

As the records of steam engineering contain but few experiments in which the weight of both the feed-water pumped into the boiler, and of the water delivered by the air-pump into the hot-well, was simultaneously ascertained, with the accompanying temperatures, pressures, etc., as well as the horse-powers developed by the engine, and the conditions under which the steam was used, it seemed to the writer that the lesson, so seldom given, was too valuable to neglect; and he has, therefore, analyzed these experiments from his own point of view, to ascertain what they really taught. It is to little purpose that experiments are made, if their reports are to contain only the observed data, without reduction, analysis, and an exposition of the causes to which the effects are due. They should be made, too, in such a manner as to be correlated, so that truths not inferable from any isolated experiment can be deduced from a combination of several.

The experiments under review, when fully interpreted, give valuable evidence on one of the most important problems in steam engineering, namely, the relative economic efficiency of different measures of expansion for steam; but nothing in the original report states the fact that these experiments were made with different measures of expansion, the reader being left to obtain that knowledge from one representative indicator diagram given for each experiment; and it is on this single diagram that the writer has been obliged to depend for the fraction of the stroke of the piston completed when the steam was cut off, and for the back pressure in the cylinder resisting the piston. The number of indicator diagrams taken was entirely too small; one every half-hour from each end of the cylinder, with a cut-off valve regulated by a governor, and variable with the speed of piston, is not enough for experiments of only a few hours' duration; they should be taken every few minutes, and the mean point of cutting off given from them, as well as the mean initial pressure in the cylinder, pressure at the point of cutting off, final pressure, back pressure and indicated pressure. All these are most important quantities, not one of which can be omitted without incompleteness; they should be as accurately ascertained as the weight of water and coal.

The experiments were made both with and without steam in the cylinder jackets, and should have been available for solving the important problem of the economic value of the steam-jacket; but as

no two experiments were made with the steam used with the same measure of expansion, they are useless for this solution, yet comparative results are presented without reference to the fact that, owing to want of equality in this condition, no comparison is possible.

Notwithstanding, however, defects of method, doubtless not within the control of the experimenter, the data of these experiments are well worth a careful examination.

### ENGINE.

The engine consists of one horizontal, direct-acting cylinder, fitted with a jet condenser and an air-pump. The cylinder is steam-jacketed on sides and ends, and has a Dack's cut-off valve, regulated by a high-speed governor of the Porter type. There is no throttle-valve, and the steam admission is controlled by the cut-off valve alone, which is variable from zero to three-fourths of the stroke of the piston. The steam-pipe delivers the steam direct into the valve-chest, and the steam-jackets are supplied with boiler steam by a small independent pipe. The cushioning of the steam, and the lead of the exhaust, are quite insignificant.

The following are the principal dimensions of the engine required to be known, in connection with the experiments:

| | |
|---|---|
| Number of cylinders, | 1. |
| Diameter of cylinder, | 30 in. |
| Stroke of piston, | 42 in. |
| Net area of piston, exclusive of piston-rod, | 702·387 sq. in. |
| Space displacement of piston per stroke, | 17·0719 cu. ft. |
| Space at one end of cylinder, in clearance and steam-passage, including capacity of valves, | 1·1407 cu. ft. |
| Length of steam-port, | 18 in. |
| Breadth of steam-port, | $2\frac{1}{4}$ in. |
| Area of steam-port, | 40·5 sq. in. |
| Clearance of the piston, | $\frac{5}{16}$ in. |

With this engine two boilers were alternately employed (only one at a time), namely, the Sinclair boiler and the common Lancashire boiler.

The steam-pipe connecting the engine with the Sinclair boiler, was 61 feet long, of which the first 23 feet were 7 inches in diameter, and the remainder 6 inches. In this pipe there were 7 elbows and an intermediate valve.

The steam-pipe connecting the engine with the Lancashire boiler, was 70 feet in length, and of the uniform diameter of 6 inches. In this pipe there were also 7 elbows.

Both steam-pipes were well covered with Fleming's composition.

### SINCLAIR BOILER.

The Sinclair boiler consists of 2 parallel vertical flat water-spaces connected by nearly horizontal wrought iron tubes, beneath which is the furnace. The flat water-spaces form the front and back of the boiler, the sides and top of which are of brick masonry, enclosing the tubes and furnace. At the top of the flat water-spaces, connecting them, and lying parallel with the water-tubes, are two horizontal cylinders of boiler-plate at different elevations, the lower one being half filled with water and half filled with steam, while the upper one is wholly filled with steam. The flat water-spaces and all the water-tubes are solidly filled with water. The furnace has no crown, and the gases of combustion at once envelop the water-tubes over the entire exterior surfaces of which they are made to circulate by means of horizontal baffling-plates interposed between the tubes. The furnace-grate is 6 feet 7 inches wide, and 6 feet long, presenting an area of 39·5 square feet, and it is fired through two doors perforated for air admission, above the incandescent fuel.

The water-tubes are 105 in number, all of which are 11 feet 9 inches long between the flat water-spaces; 99 are of 4 inches external diameter, and the remaining 6 are of 5 inches external diameter. The 6 tubes are arranged 3 on each side of the furnace; and the 99 are arranged over the grate in 11 rows vertically, each row containing 9 tubes so placed that they are opposite the spaces between the adjacent rows above and below. The entire height occupied by the tubes, from the bottom of the lower row to the top of the upper row, is 6 feet 6 inches; and from the bottom of the lower row to the top of the grate bars, is 20 inches. From the top of the upper row to the bottom of the upper steam-cylinder, or reservoir, is 30 inches; this reservoir being placed over the centre of the boiler, and encased in the brick masonry, with the exception of the lower fifth of its periphery, which is exposed, as a steam-superheating surface, to the gases of combustion just before their exit into the chimney.

The remaining steam-cylinder, or reservoir, is placed upon one of the side walls; it has one-seventh of its periphery in contact with the

gases of combustion, and nearly one-half of its periphery in contact with the atmosphere. The horizontal diameter of the lower reservoir is 2 feet below that of the upper one. Both cylinders are 4 feet in diameter and 16 feet 9 inches in length.

The flat water-spaces are strongly stayed, to resist the steam pressure.

The total water-heating surface of the boiler, calculated for the *inner* circumference of the tubes, is 1420 square feet, being 35·95 square feet per square foot of grate surface.

### LANCASHIRE BOILER.

There were three Lancashire boilers situated by the side of the Sinclair boiler, and all four discharged their gases of combustion into a common flue. The Lancashire boiler experimented with was the one adjacent to the Sinclair boiler. It had a cylindrical shell, 7 feet in diameter and 25 feet 3 inches in length, set in masonry. This shell contained two cylindrical flues, of 2 feet 9 inches diameter, extending its whole length. The front end of these flues was occupied by the furnaces, whose grates were 6 feet 8 inches long. The aggregate grate surface was thus 36·6 square feet.

The gases of combustion, after leaving the furnace flues, returned on each side of the shell, to the front of the boiler, whence they descended into one common flue beneath the shell, and thence flowed towards the chimney at the back of the boiler. The flues at the sides and below the shell were made in the masonry of its setting.

The total heating surface was 698·5 square feet, or 19·08 square feet per square foot of grate surface.

### FEED-WATER HEATER.

In the flue which received in common the gases of combustion from the Lancashire boilers and the Sinclair boiler, there was a feed-water heater, and, as the temperature in this flue was over 800 degrees Fahrenheit, that heater was very efficient. Although only one of those boilers was in use at a time, to supply the experimental engine, yet the others were in use for other purposes, and thus the temperature of the flue was maintained. The boiler in use for the experimental engine was shut off from the others by a stop-valve. The heater was used in only the first two experiments, namely, A and B

in the following table; in the remaining three experiments, the feed-water was pumped directly from the measuring tank into the boiler.

### MANNER OF MAKING THE EXPERIMENTS.

The experiments were made in the paper mills of Messrs. Robert Craig & Sons, at Dalkeith, Scotland; and each lasted during the middle portion of the working day. All the coal burned was weighed by Mr. Sinclair, the patentee of the boiler, who also superintended the firing. The thickness and condition of the fires at the end of an experiment were left the same as at the beginning, as nearly as could be judged by the eye. The water level and steam pressure were also left the same at the end as at the beginning of an experiment.

The measurements of the feed-water consumed were made by Mr. D. Crichton, R. N. Those of the water discharged from the hot-well were made by Prof. John Lockie, of Edinburgh. The indicator diagrams were taken every half-hour, from each end of the cylinder, by Mr. A. Masson, manager of the firm from whose designs the engine was built. Each of these gentlemen had assistants. The supervision of the entire experiments was by Mr. Lavington E. Fletcher, assisted by Mr. Richard Thompson, one of the inspectors of his Association. There was no lack of competent persons to secure accurate observations, and there is no doubt those recorded are scrupulously exact.

The feed-water was taken from the hot-well tanks and measured in an open tank of 4 feet cube, from which it was pumped into the boiler by a steam-pump placed immediately over the tank. The suction pipe of this pump reached to within a few inches of the bottom of the tank, and carried a scale of feet and inches, from which the depth pumped out could be at any moment noted. The tank was pumped out to within 6 inches of the bottom, and it was always filled to a fixed point, so as to give a depth of 2 feet 6 inches for each tankful. The time at which each tank was emptied was noted in a tabular log.

The water discharged from the hot-well was measured in two tanks, each 10 feet long, 4 feet wide and 3 feet deep, with a sluice-valve at the bottom for emptying. The water from the hot-well could be directed into either tank at will, and one was being filled while the other was being emptied. The tanks had covers in which were large manholes and a number of smaller holes kept open for freeing

the air and vapor. The tanks were about 8 feet from the air-pump, and the time of filling one averaged about 6 minutes.

## DESCRIPTION OF THE TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS.

The data and results of the experiments will be found in the following table, in which the columns—each containing an experiment—have been lettered, and the lines containing the quantities have been grouped and numbered, for facility of reference.

Experiments A, B and C were made with steam of the boiler pressure in the cylinder-jackets; and experiments D and E were made with the steam shut off from these jackets. In every experiment the steam was used with a different measure of expansion.

In experiments A and B, the feed-water, after being measured in the tank, was pumped through the heater, and received a considerable accession of temperature before entering the boiler. In the remaining experiments, the feed-water was pumped direct from the tank into the boiler.

Two kinds of coal were used. Welsh semi-bituminous, from the Duffryn mines, in experiment B; and Scotch bituminous, from the Marquis of Lothian's mines, in the remaining experiments.

The Sinclair boiler was employed in experiments A, B and E; and the Lancashire boiler in experiments C and D.

Experiment C would have been continued seven consecutive hours, but for a leakage from the blow-out tap at the bottom of the boiler, by which means 2½ hours were lost.

Line 1 contains the date of the experiment.

Lines 2 and 3 contain, respectively, the number of square feet of grate-surface and of heating-surface in the boilers.

*Total Quantities.*—Lines 4 to 13, both inclusive, contain the total quantities counted, weighed or measured.

Line 4 gives the duration of the experiments in consecutive hours.

Line 5 gives the kind of coal consumed.

Line 6 contains the total number of pounds of coal consumed, during the experiments, as given by careful weighing; the thickness and condition of the fires, the height of water in the boiler, and the steam-pressure on it, being supposed the same at the end as at the beginning of the experiments.

Line 7 gives the total number of cubic feet of feed-water pumped into the boilers, from a tank in which it was carefully measured.

Line 8 gives the weight of this water in pounds, obtained by multiplying the quantities on line 7 by the weights, respectively, of a cubic foot of water at the temperatures on line 20. These quantities are too small, by the amounts vaporized under the atmospheric pressure from the water-surface in the open tank.

Line 9 gives the total number of pounds of water of condensation withdrawn from the steam-jackets of the cylinder during the experiments. This quantity was obtained by measurement in a tank, and is, necessarily, too small, as the water within the jackets resulting from the condensation of the steam therein, had the temperature due to the pressure of that steam, and much greater than the temperature normal to the lessened pressure of the atmosphere into which it immerged, the heat due to the difference of the two temperatures vaporizing a portion of the water as it trickled from the jackets, and while it was filling the tank.

Line 10 gives the total number of pounds of steam which passed through the cylinder during the experiments. This quantity was obtained by deducting the quantities on line 9 from those on line 8.

Line 11 gives the total number of cubic feet of water which flowed from the hot-well into the tanks, where it was carefully measured. This quantity is the sum of the feed-water pumped into the boilers, and of the injection-water admitted to the condenser.

Line 12 gives the weight of this water in pounds, obtained by multiplying the quantities on line 11 by the weights, respectively, of a cubic foot of water at the temperature on line 23. These quantities are, necessarily, too small, by the quantities vaporized under the atmospheric pressure from the open surface of the water in the tanks.

Line 13 contains the total number of double strokes made by the steam piston during the experiments, or of revolutions made by the crank-shaft of the engine.

*Engine.*—Lines 14 to 19, both inclusive, show the principal conditions under which the engine was operated during the experiments.

Line 14 gives the steam-pressure in the boiler, and line 15 gives it in the steam-pipe near the cylinder, in pounds per square inch above the atmosphere.

Line 16 gives the proportion of throttle-valve open; as there was no throttle-valve, the opening was "wide."

Line 17 gives the fraction of the stroke of the piston completed when the steam was cut off, as obtained in each experiment from the representative indicator diagram furnished with Mr. Fletcher's report. The point of cutting off was assumed to be where the convex throttled curve reversed into the concave expansion curve of the diagram.

Line 18 gives the number of times the steam was expanded for each experiment, and includes the effect of the space in the cylinder clearance and steam-passage.

Line 19 gives the mean number of double strokes made by the steam-piston per minute.

*Temperatures.*—Lines 20 to 24 contain mean temperatures in Fahrenheit degrees.

Line 20 gives the temperature of the feed-water in the tank when it was measured; and line 21 gives its temperature when it entered the boiler.

The quantities on line 21 show the temperature of the feed-water when it entered the boiler.

Line 22 gives the temperature of the injection water.

Line 23 gives the temperature of the water on entering the tanks from the hot-well. These tanks were 8 feet from the air-pump.

All the above temperatures were taken by common mercurial thermometers; but the temperature of the gases of combustion emerging from the experimental boilers, was taken by a metallic pyrometer, and is given on line 24.

*Rate of Combustion.*—The number of pounds of coal consumed per hour, and per hour per square foot of the grate- and heating-surfaces of the boiler, are given on lines 25, 26 and 27, respectively.

*Steam-Pressures in Cylinder, per Indicator.*—Lines 28 to 33, both inclusive, contain the mean steam-pressures in the cylinder, as given by the indicator diagrams.

Line 28 gives the pressure of the steam on the piston at the beginning of its stroke; and line 29 gives that pressure at the end of its stroke—in both cases, in pounds per square inch above zero.

Line 30 gives the indicated pressure on the piston, in pounds per square inch; and line 31 gives the back pressure of the uncondensed steam against the piston in pounds per square inch. This latter

quantity is taken from the representative diagram given for each experiment in Mr. Fletcher's report.

Line 32 gives the net pressure on the piston in pounds per square inch. It is the indicated pressure on line 30, less 2 pounds per square inch, assumed for the pressure per square inch of piston to work the engine, *per se*, or the unloaded engine.

Line 33 gives the total pressure on the piston in pounds per square inch. It is the indicated pressure on line 30, plus the back pressure on line 31.

*Horse-Powers.*—Lines 34, 35 and 36 contain, respectively, the mean indicated, net and total horse-powers developed by the engine during the experiments, and are calculated for the pressures on lines 31, 32 and 33.

Line 37 gives the total horse-powers developed by the expanded steam after the closing of the cut-off valve, obtained, as nearly as possible, from the representative indicator diagrams above referred to. These quantities are only of use in computing those on lines 48, 58 and 59.

*Economic Results.*—Lines 38 to 46, both inclusive, give the economic results obtained from the machinery under the experimental conditions.

Lines 38, 39 and 40 show, respectively, the cost of the indicated, net and total horse-powers in pounds of coal consumed per hour. The quantities on these lines are the quotients of the division of the quantities on line 25, by those on lines 34, 35 and 36. It must not be overlooked that these results are not properly comparable in the different experiments, because they are from different kinds of boiler, different kinds of coal, different rates of combustion, and different temperatures of feed-water.

Lines 41, 42 and 43 show, respectively, the cost of the indicated, net and total horse-powers in pounds of feed-water consumed per hour. The quantities on these lines are the quotients of the division of the quantities on line 8, by those on line 4, and by those on lines 34, 35 and 36; and these quotients would be strictly comparable for the different experiments, were the units of heat in a pound of steam the same at all pressures. But as they vary, it is necessary to substitute the number of units of heat consumed per hour per horse-power for the pounds of steam; and this has been done on lines 44, 45 and 46, whose quantities were obtained by multiplying those on lines 41,

42 and 43 by the number of Fahrenheit units in a pound of steam of the pressure on line 14, with a uniform temperature for the feed-water of 100° Fahrenheit.

*Condensation in Cylinder.*—Lines 47 to 51, both inclusive, contain the quantities necessary for ascertaining the condensation undergone by the steam in the cylinder, independent of the condensation therein effected by the transmutation of heat into the power on line 37 developed by the expanded steam, or after the closing of the cut-off valve.

Line 47 gives the number of pounds of steam discharged, during the experiments, from the cylinder into the condenser, calculated from the weight of a cubic foot of steam of the pressure at the end of the stroke of the piston on line 29, from the number of double strokes of piston on line 13, and from the number of cubic feet of piston displacement per stroke plus the space in the cylinder clearance and steam-passage at one end, allowing deductively for the weight of steam already present in that space when the piston begins its stroke.

Line 48 contains the number of pounds of steam condensed in the cylinder, during the experiments, to produce the power on line 37, which power is developed by the expanding steam only, and is additional to the power developed by the non-expanded steam previous to the closing of the cut-off valve, the sum of the two forming the total horses-power developed by the engine, that is, the quantities on line 36.

Line 49 gives the number of pounds of water of condensation withdrawn, during the experiments, from the steam-jackets of the cylinder; these quantities are the same as those on line 9.

Line 50 contains the sum of the quantities on lines 47, 48 and 49, and, were there no cylinder condensation other than that due to the development of the power on line 37, this sum would exactly equal the weight of feed-water pumped into the boiler as given on line 8. Under no circumstances can it be greater, and by whatever quantity it is less, that quantity is the weight of steam condensed in the cylinder by all causes other than the production of the power above referred to.

Line 51 contains this less quantity for the different experiments, expressed in per centum of the weight of feed-water pumped into the boiler.

*Vaporization.*—Lines 52 to 55, both inclusive, give the vaporizations, during the experiments, that would have been, had the feed-water been pumped into the boilers at the temperatures of 100° and 212° Fahrenheit, and vaporized under the standard atmospheric pressure of 29·92 inches of mercury. These equalizations are necessary in order to determine the relative economic efficiencies of the boilers, and of the coal at the different rates of combustion.

Line 52 contains what would have been the vaporization from the temperature of 100° Fahrenheit; and line 53 contains what would have been the vaporization from the temperature of 212° Fahrenheit.

Line 54 contains the quotients of the division of the quantities on line 52 by those on line 6; and line 55 similarly contains the quotients of the division of the quantities on line 53 by those on line 6. These quotients show the number of pounds of water vaporized by 1 pound of coal, from the temperatures of 100° and 212° Fahrenheit, and under the standard atmospheric pressure in the respective boilers, and with the experimental rates of combustion.

*Comparison of the Heat imparted to the Steam in the Boiler, and accounted for in the Hot-Well.*—Lines 56 to 62, both inclusive, contain the quantities necessary for comparing the amounts of heat imparted to the steam in the boiler and in the condenser, above the temperature of the hot-well, with the amounts accounted for in the condensing water above the temperature of the injection and by the production of the total horse-powers developed by the expanded steam after the closing of the cut-off valve.

[To be continued.]

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**Movement of Tempests.**—M. Faye has studied tempests as moving whirlpools with vertical axes, comparing them to the eddies of streams. In the course of a river, as soon as there is any difference of velocity between contiguous portions of water, such eddies tend to be produced. As soon as the tendency becomes effective, it can be mathematically shown that the angular velocity of rotation increases in the inverse ratio of the square of the distance from the axis. Moreover, although the eddy is plunged in the mass of the surrounding water, it will remain isolated, as it were, by a surface of its own, which is a surface of revolution around the vertical axis, with the concavity of its meridian generatrix turned downward.—*Comptes Rendus.* C.

# STEAM.

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ROUND THE CYLINDER.

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C.

# ECONOMIC VAPORIZATION OF WATER A

By Chief Engineer ISHERWO

Table containing the Data and Results of the Experiments made by Mr. LAVINGTON E. FLETCHER at Dalkeith, Scotl
for the experimental conditions, the Economic Vaporization of each of the two kinds of Boiler experi
Efficiency of the Different Measures of Expansion with which the Steam v

| No. of Line. | | |
|---|---|---|
| 1 | | Date of Experiment, |
| 2 | BOILER. | Square feet of grate surface in use, |
| 3 | | Square feet of heating surface in use, |
| 4 | TOTAL QUANTITIES. | Duration of experiment, in consecutive hours, |
| 5 | | Kind of coal consumed, |
| 6 | | Total number of pounds of coal consumed, |
| 7 | | Total number of cubic feet of feed-water pumped into the boiler, |
| 8 | | Total number of pounds of feed-water pumped into the boiler, |
| 9 | | Total number of pounds of water of condensation withdrawn from cylinder jacket, |
| 10 | | Total number of pounds of water passing through the cylinder as steam, |
| 11 | | Total number of cubic feet of condensing-water and feed-water measured in hot-well, |
| 12 | | Total number of pounds of condensing-water and feed-water measured in hot-well, |
| 13 | | Total number of double strokes made by the steam-piston, |
| 14 | ENGINE. | Steam pressure in boiler, in pounds per square inch above atmosphere, |
| 15 | | Steam pressure in steam-pipe near cylinder, in pounds per square inch above atmosphere, |
| 16 | | Proportion of throttle-valve open, |
| 17 | | Fraction of the stroke of the piston completed when the steam was cut off, |
| 18 | | Number of times the steam was expanded, |
| 19 | | Number of double strokes made per minute by the steam-piston, |
| 20 | TEMPERATURES. | Temperature, in degrees Fahrenheit, of the feed-water in the tank, |
| 21 | | Temperature, in degrees Fahrenheit, of the feed-water when pumped into the boiler, |
| 22 | | Temperature, in degrees Fahrenheit, of the injection water, |
| 23 | | Temperature, in degrees Fahrenheit, of the hot-well, |
| 24 | | Temperature, in degrees Fahrenheit, of the gases of combustion in the chimney, |
| 25 | RATE OF COMBUSTION. | Pounds of coal consumed per hour, |
| 26 | | Pounds of coal consumed per hour per square foot of grate surface, |
| 27 | | Pounds of coal consumed per hour per square foot of heating surface, |
| 28 | STEAM PRESSURES IN CYLINDER Per Indicator. | Steam pressure in cylinder, in pounds per square inch above zero, at beginning of stroke of piston, |
| 29 | | Steam pressure in cylinder, in pounds per square inch above zero, at end of stroke of piston, |
| 30 | | Mean indicated steam pressure on pistons, in pounds per square inch, |
| 31 | | Mean back pressure against piston, in pounds per square inch, |
| 32 | | Mean net pressure on piston, in pounds per square inch, |
| 33 | | Mean total pressure on piston, in pounds per square inch, |
| 34 | HORSES-POWER. | Indicated horses-power developed by the engine, |
| 35 | | Net horses-power developed by the engine, |
| 36 | | Total horses-power developed by the engine, |
| 37 | | Total horses-power developed by the expanded steam after the closing of the cut-off valve, |
| 38 | ECONOMIC RESULTS. | Pounds of coal consumed per hour per indicated horse-power, |
| 39 | | Pounds of coal consumed per hour per net horse-power, |
| 40 | | Pounds of coal consumed per hour per total horse-power, |
| 41 | | Pounds of feed-water consumed per hour per indicated horse-power, |
| 42 | | Pounds of feed-water consumed per hour per net horse-power, |
| 43 | | Pounds of feed-water consumed per hour per total horse-power, |
| 44 | | Fahrenheit units of heat consumed per hour per indicated horse-power, |
| 45 | | Fahrenheit units of heat consumed per hour per net horse-power, |
| 46 | | Fahrenheit units of heat consumed per hour per total horse-power, |
| 47 | CONDENSATION IN CYLINDER. | Pounds weight of steam discharged from the cylinder into the condenser, calculated from the pressure at the of the stroke of the piston, |
| 48 | | Pounds weight of steam condensed in the cylinder to produce the power developed by the expanded steam a the closing of the cut-off valve, |
| 49 | | Pounds of water withdrawn from the jacket of the cylinder, |
| 50 | | Sum of the above three quantities, |
| 51 | | Difference between the weight of water pumped into the boiler, and the immediately above quantity, in per cen of the former; being the per centum of the steam evaporated in the boiler, condensed in the cylinder, |
| 52 | VAPORIZATION. | Pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury, |
| 53 | | Pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury, |
| 54 | | Pounds of water vaporized from 100 degrees Fahrenheit by one pound of coal, |
| 55 | | Pounds of water vaporized from 212 degrees Fahrenheit by one pound of coal, |
| 56 | HEAT IMPARTED TO THE STEAM IN THE BOILER AND ACCOUNTED FOR IN THE HOT-WELL. | Number of Fahrenheit units of heat imparted to the steam in the boiler above the temperature of the water in hot-well, |
| 57 | | Number of Fahrenheit units of heat added to the steam in the condenser, |
| 58 | | Number of Fahrenheit units of heat taken from the water of condensation due to the production of the powe |
| 59 | | Number of Fahrenheit units of heat equivalent to the total horses-power developed by the expanded steam, or a the closing of the cut-off valve, |
| 60 | | Number of Fahrenheit units of heat which should have been found in the condensing-water above its tempera when injected, being the difference of the quantity on line 59 and the sum of the quantities on lines 56 and 58, |
| 61 | | Number of Fahrenheit units of heat in the condensing-water above its temperature when injected, |
| 62 | | Difference between the number of Fahrenheit units of heat which should have been found in the condensing-w above its temperature when injected, and the number that were found, in per centum of the latter; b the per centum of heat lost by steam and water leakage from boiler and engine, by difference of evapora into the atmosphere from the surface of the water in the tanks for measuring the feed-water and the well water, by external radiation from the surfaces of the exhaust pipe, condenser, air-pump and hot-v and due to errors of observation, |

# ATER AND EXPANSION OF STEAM.

SHERWOOD, U. S. NAVY.

KEITH, SCOTLAND, ON THE ENGINE AND BOILERS OF THE PAPER MILL BELONGING TO ROBERT CRAIG & SONS, DETERMINING, OILER EXPERIMENTED WITH, AND OF THE TWO KINDS OF COAL CONSUMED; ALSO, THE RELATIVE ECONOMIC THE STEAM WAS USED, AND OF THE STEAM-JACKET AROUND THE CYLINDER.

| | STEAM IN CYLINDER JACKET. | | | NO STEAM IN CYLINDER JACKET. | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| . . . | FEBRUARY 7, 1877. | FEBRUARY 8, 1877. | FEBRUARY 12, 1877. | FEBRUARY 9, 1877. | FEBRUARY 10, 1877. |
| . . . | 39·5 | 39·5 | 36·6 | 36·6 | 39·5 |
| . . . | 1420·0 | 1420·0 | 698·5 | 698·5 | 1420·0 |
| . . . | 6· | 7· | 4½· | 7· | 7· |
| . . . | Scotch. | Welsh. | Scotch. | Scotch. | Scotch. |
| . . . | 3136· | 2954· | 3752· | 5936· | 4592· |
| . . . | 456·00 | 505·33 | 352· | 551·33 | 531·33 |
| . . . | 28359·3254 | 31413·2669 | 21873·1262 | 34288·1097 | 33003·3626 |
| . . . | 936·0000 | 1092·0000 | 702·0000 | | |
| . . . | 27423·3254 | 30321·2669 | 21171·1262 | 34288·1097 | 33003·3626 |
| . . . | 7060· | 7980· | 6700· | 9040· | 8430· |
| . . . | 437861·2565 | 494367·1606 | 416038·7311 | 559802·9492 | 521794·2643 |
| . . . | 19296· | 22176· | 13446· | 22050· | 22050· |
| . . . | 57·5 | 57·5 | 32·5 | 37·5 | 32·5 |
| . . . | 53·3 | 52·3 | 31·0 | 34·7 | 31·8 |
| . . . | Wide. | Wide. | Wide. | Wide. | Wide. |
| . . . | 0·120 | 0·173 | 0·500 | 0·380 | 0·346 |
| . . . | 5·710 | 4·448 | 1·882 | 2·3876 | 2·5842 |
| . . . | 53·6 | 52·8 | 49·8 | 52·5 | 52·5 |
| . . . | 90·59 | 83·65 | 85·22 | 80·60 | 88·80 |
| . . . | 223·00 | 183·84 | 85·22 | 80·60 | 88·80 |
| . . . | 41·00 | 41·00 | 41·50 | 41·00 | 44·00 |
| . . . | 96·43 | 102·58 | 90·90 | 104·67 | 106·80 |
| . . . | 400·00 | 400·00 | over 800·00 | over 800·00 | 450·00 |
| . . . | 522·6667 | 422·0000 | 833·7778 | 848·0000 | 656·0000 |
| . . . | 13·2321 | 10·6885 | 22·7808 | 23·1694 | 16·6076 |
| . . . | 0·3680 | 0·2972 | 1·1937 | 1·2112 | 0·4620 |
| ton, . . . | 58·97 | 58·02 | 41·48 | 41·88 | 39·78 |
| . . . | 11·84 | 13·00 | 14·14 | 14·00 | 12·52 |
| . . . | 23·50 | 24·72 | 23·64 | 22·28 | 20·82 |
| . . . | 3·00 | 2·50 | 3·00 | 3·75 | 2·50 |
| . . . | 21·50 | 22·72 | 21·64 | 20·28 | 18·82 |
| . . . | 26·50 | 27·22 | 26·64 | 26·03 | 23·32 |
| . . . | 187·669 | 194·465 | 175·403 | 174·275 | 162·855 |
| . . . | 171·697 | 178·732 | 150·563 | 158·631 | 147·411 |
| . . . | 211·627 | 214·132 | 197·662 | 203·607 | 182·410 |
| . . . | 155·7 | 136·6 | 53·0 | 85·3 | 80·1 |
| . . . | 2·7850 | 2·1700 | 4·7535 | 4·8659 | 4·0281 |
| . . . | 3·0441 | 2·3611 | 5·5377 | 5·3458 | 4·4501 |
| . . . | 2·4698 | 1·9707 | 4·3053 | 4·1649 | 3·5963 |
| . . . | 25·1856 | 23·0767 | 27·7116 | 28·1067 | 28·9507 |
| . . . | 27·5285 | 25·1080 | 32·2835 | 30·8786 | 31·9838 |
| . . . | 22·3344 | 20·9572 | 24·5909 | 24·0576 | 25·8471 |
| . . . | 27878·3990 | 25544·0195 | 30441·3007 | 30929·8185 | 31802·2569 |
| . . . | 30471·8277 | 27792·5022 | 35463·5487 | 33980·1361 | 35134·3290 |
| . . . | 24722·3538 | 23197·9061 | 27011·1996 | 26474·0151 | 28395·3372 |
| ressure at the end . . . | 20740·6865 | 26178·3459 | 17264·6826 | 28032·4042 | 25066·2765 |
| anded steam after . . . | 2605·9558 | 2667·3249 | 650·9295 | 1599·3748 | 1530·2987 |
| . . . | 926·0000 | 1092·0000 | 702·0000 | | |
| . . . | 24272·6423 | 29037·6708 | 18617·6121 | 29631·7790 | 26596·5752 |
| ity, in per centum he cylinder, . | 14·4104 | 4·6974 | 14·8836 | 13·5800 | 19·4125 |
| emperature of 100 . . . | 25820·9709 | 29708·1452 | 22577·1841 | 35609·8146 | 33955·9335 |
| emperature of 212 . . . | 28837·9094 | 33261·1360 | 25215·1165 | 39760·1327 | 37923·3653 |
| . . . | 8·2337 | 10·0569 | 6·0174 | 5·9990 | 7·3946 |
| . . . | 9·1958 | 11·2597 | 6·7204 | 6·6981 | 8·2586 |
| f the water in the . . . | 28370321·3844 | 31181375·1175 | 21852889·6032 | 34981137·5444 | 33540066·5829 |
| . . . | 1514609·8326 | 1686142·0400 | 1244688·7420 | 1983153·6167 | 1916578·6572 |
| n of the power, . | 387571·6750 | 407432·4632 | 103444·9382 | 258568·3235 | 231554·2053 |
| ded steam, or after . . . | 2343637·6480 | 2398829·2861 | 598327·5306 | 1497951·2306 | 1406634·1568 |
| ve its temperature es on lines 56, 57 . . . | 27928865·2440 | 30876120·3346 | 22602690·7528 | 35724908·2540 | 34275565·2886 |
| ed, . . . | 22774282·1632 | 28610102·6961 | 19524823·4925 | 33501368·1694 | 30737932·5899 |
| e condensing-water the latter; being nce of evaporation ater and the hot- ump and hot-well, . . . | 22·6336 | 7·9203 | 15·7668 | 6·6372 | 11·509 |

# MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. PICTET.

Translated for the JOURNAL OF THE FRANKLIN INSTITUTE, by P. PISTOR, M. E.

[Continued from Vol. lxxvi, page 111.]

## IV.—CALCULATION OF THE DENSITY OF LIQUID OXYGEN.

### MAXIMUM TENSIONS.

If we discuss the results of the experiments related in the preceding chapter, we can deduce several consequent conclusions on the physical properties of liquefied oxygen.

In order to do so, let us first calculate the weight of oxygen liberated during the reaction. We have the formula:

$$2\,KCl.\,O^3 = KCl + O^6.$$

Applying it to 700 gr. of chlorate of potassa, we have

$$700 \times 39{\cdot}16 = 274{\cdot}12 \text{ grammes.}$$

To obtain the volume of this mass of gas at 0°, the weight should be divided by the sp. gr., $\delta$; $\delta = 1{\cdot}437$ (Regnault); and we get

$$\frac{274{\cdot}12}{1{\cdot}437} = 191{\cdot}4 \text{ litres.}$$

These 191·4 litres have been heated to 485°, and fill a volume composed of two parts.

1. The empty space above the chloride of potassium.
2. The volume of tube *A*, from the flask to the manometer.

Let us designate the first by $v$, the second by $v'$.

Imagine $v$ and $v'$ to be at the same temperature of 485°, and calculate the final pressure that should be due to the liberation of 191·4 litres of oxygen.

The law of Mariotte and Gay-Lussac supposed to be correct, we have

$$(1.) \qquad P = \frac{191{\cdot}4\,(274 + 485)\,1060}{274 \times (v + v')}.$$

$v$ and $v'$ are expressed in cubic centimetres.

The weight of the water necessary to fill the flask after the experiments gives

$v = 944$ cubic centimetres exactly.

As to $v'$, it is equal to the cross-section of the tube multiplied by its total length. The tube is 4 mm. in diameter and 4·16 m. in length, therefore

$$v' = \pi \cdot 0{\cdot}2^2 \times 4{\cdot}16 \text{ m.} = 52{\cdot}25 \text{ cubic centimetres.}$$

Substituting for $v$ and $v'$, in equation (1), their values, we find the value of $P$. The temperature, 485°, which acts on the volume, $v$, is duly considered if we take as a coefficient of the expansion of iron,

$$k = 0{\cdot}0000122045,$$

and we get the final formula,

$$(2.) \qquad P = \frac{191{\cdot}4\,(274 + 485)\,1000}{274\,[944\,(1 + 485 \times 3 \times 0{\cdot}0000122045) + 52{\cdot}25]}.$$

$$P = 532{\cdot}10 \text{ atmospheres.}$$

We see, from the above, that the pressure corresponding to the production of 191·4 litres of oxygen is a maximum of 532·10 atmospheres. This pressure was not reached, but was closely approached; we saw the manometer at 522, 524, 517 atmospheres, but never exceeding 526 (third experiment).

The pressure, on the contrary, after having rapidly fallen, remained stationary during several minutes. This stoppage in the movement of the hand of the manometer, is an evident indication that the condensation had also come to a standstill. What can be the cause?

But one is admissible: it is, that the condensing tube is full of liquid. If it were not, condensation would infallibly continue, as the temperature is kept constant by the action of more than two kilogrammes of solid carbonic acid, or of protoxide of nitrogen.

It is therefore necessary t know exactly, the volume of that part of the tube where condensation can take place.

Between the manometer $m'$, and the upper end of the tube containing carbonic acid, I find a distance of exactly 3·62 m. The volume $v$ (wherein the oxygen liquefies) is therefore

$$(3.) \qquad v = \pi\, 0{\cdot}2^2 \times 3{\cdot}62 \text{ m.} = 45{\cdot}467 \text{ cubic centimetres.}$$

The temperature of this tube is about — 120° and tends to diminish its volume; on the other hand, it is subjected to a very considerable pressure on the inside, which tends to increase its volume. Both these causes produce but small results, numerically speaking, and opposed to one another. Without any great error, we can therefore use the value as it is.

Let us calculate, for each experiment, the difference between the theoretical pressure which should be attained without condensation, and the "stationary pressure" obtained before the first jet. We would then have an estimate of the variation in volume, corresponding to the change of condition produced.

| | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| Theoretical pressure, | 532·10 | 532·10 | 532·10 | 532·10 | 532·10 |
| Observed " | 470· | 471· | 471· | 469· | 469· |
| Differences, | 62·10 | 61·10 | 61·10 | 63·10 | 63·10 |

The mean of these five experiments gives 62·1 atmospheres as the difference.

The weight in grammes, represented by a variation of 1 atmosphere can be calculated. Let us designate it by $p$. We have the formula:

$$(4.) \qquad p = \frac{274{\cdot}12}{532{\cdot}10} \text{ grammes} = 0{\cdot}51517 \text{ gr.}$$

Therefore the weight $F$ of the liquefied oxygen is equal to

$$(5.) \qquad F = \frac{274{\cdot}12}{532{\cdot}10} \times 62{\cdot}10 + \left\{ \begin{array}{l} \text{The weight of the gas contained} \\ \text{in the tube before liquefaction.} \end{array} \right.$$

When calculating the maximum theoretical pressure, we have supposed the whole volume $v + v'$ occupied by the gas, to be at a temperature of $+ 485°$. We should therefore calculate the weight of compressed gas in the volume $v'$ at 485°. This weight is determined by the proportion.

$$(6.) \qquad 996{\cdot}25 : 274{\cdot}12 :: 45{\cdot}467 : x,$$

from which $x$ may be found

$$x = 12{\cdot}51 \text{ grammes.}$$

The variation of pressure observed before the first jet, indicates the variation of volume corresponding to the change of condition; the weight of condensed gas is therefore: "the sum of the weight of gas in the tube before condensation, plus the weight of gas represented by the diminution of pressure." Calling this weight $R$, its value is

$$(7.) \qquad R = 12{\cdot}51 + 62{\cdot}1 \times 0{\cdot}51517 \text{ grammes.}$$

$$R = 44{\cdot}502 \text{ grammes.}$$

The volume occupied by this liquid is equal to $v'$, therefore,

(8.) $\frac{R}{v'}$ = the density of liquid oxygen $d$,

consequently

$$\frac{44{\cdot}502}{45{\cdot}467} = d = 0{\cdot}9787.$$

This is therefore the density of liquid oxygen, deduced from direct observations made during the five experiments, with this object in view.

M. Dumas, perpetual secretary of the Academy of Sciences at Paris, wrote to us the following remarks on the 26th of last December.

"Allow me to add that, if I am not mistaken, the density of liquid oxygen must be equal to that of water.

"The density of sulphur being 2, what I called its atomic volume, about 60 years ago at Geneva, itself would be equal to $\frac{32}{2} = 16$.

"The isomorphous bodies having the same atomic volume, that of oxygen taken as 16, would give $\frac{16}{16} = 1$ for the density of solid oxygen, and almost this figure for the liquid state.

"The atomic volume of phosphorous being 15·5, we would have for nitrogen $\frac{14}{15{\cdot}5} = 0{\cdot}9$, and more probably 0·45, on account of the doubled state of its molecule.

"The atomic volume of magnesium being 13·8, that of hydrogen would be $\frac{1}{13{\cdot}8} = 0{\cdot}07$, at least.

"This volume might be much higher, if hydrogen, like potassium and sodium, presented, in a disengaged state, a much larger volume than that assumed in a combined state.

"These surmises may be of some value in explaining the probable condition of the liquid you should obtain. It would be very interesting to know whether the density of liquid oxygen approaches or recedes from that, one is inclined to attribute to it.

"But the problem of molecular mechanics, whose solution you seek, claims you entirely, and I would reproach myself did I divert you from it; notwithstanding the paternal interest I take in the determination of the atomic volume.

"P. S.—If hydrogen is a metal, as I have allowed myself to think since my youth, would not its condensation produce a solid amalgam, by compressing it on congealed mercury?

"In this case, the tension might be destroyed or diminished."

We are very happy to have been able, experimentally, to confirm the predictions of the illustrious chemist; and we think that this verification, obtained sixty years after the foundation of the atomic theory, is a grand triumph for its most ardent and learned advocate.

*Second Method.*—The experiments whose essential results we have given, will allow a second estimate of the density. A less accurate estimate than that we obtained from the preceding calculations, but which, nevertheless, should not be despised. We conduct this second investigation in the following manner: the regulating cock was closed after the first jet of liquid oxygen, at the well defined moment when the liquid jet was replaced by a gaseous jet. The thick mist produced by the vesicular condition of condensed oxygen at the moment of expansion will not interfere in the least with its determination, and may be observed simultaneously by several assistants. It may therefore be asserted that all the condensed liquid has escaped through the orifice, at the moment of closing the screw plug-cock. The tube must be full of gas under pressure.

This gas comes from a flask whose temperature is very high, and enters the thoroughly chilled tube. The probable temperature of the gas should be estimated at the instant of closing the plug-cock.

It is known that gases assume the temperature of the envelope containing them with extraordinary facility, especially if the spaces are restricted. We can, therefore, infer the temperature of the gas from the differences in temperature taking place in the gas which cools, and in the copper of the tube which becomes heated.

The weights of these bodies are known, also their specific heats, and their extremes of temperature: the solution is, therefore, possible.

Let us calculate the weight, $A$, of the copper tube. Its dimensions are:

| | |
|---|---|
| Exterior diameter = . . . | 15 mm. |
| Interior " = . . . | 4 " |
| Length = . . . . . | 3·62 m. |
| Density = . . . . . | 8·95. |

We have:

$$A = \pi\,(\overline{0\,75^2} - \overline{0\cdot2^2})\;362 \times 8{\cdot}95 \text{ grammes.}$$
$$A = 5319{\cdot}3 \text{ grammes.}$$

At the end of the first jet, after the condensation of the oxygen and its expulsion, the maximum temperature of the copper may be estimated at —110° as the highest limit.

Let us designate by $x$ the number of degrees to which the temperature of the copper will be raised, and, by $y$, the corresponding number of degrees the temperature of $F$ grammes of gas, contained in the tube, under pressure $P$, will be lowered.

We can form the two equations:

(9.) $5{\cdot}3193 \times c \times x = F \times k \times y.$

(10.) $x + y = 485 - (-110) = 595.$

In these equations,

$c$ = specific heat of copper, 0·094, and

$k$ = specific heat of the oxygen at a constant pressure = 0·2182.

As for $F$, it is given by the formula:

(11.) $$F = \frac{0{\cdot}045467 \times 1{\cdot}437\,(274 + x - 110) \times \text{press. in atm.}}{274.}$$

Solving these equations, we find, as numerical results:

$x = 4$ degrees.

$y = 591$ degrees.

$F = 16{\cdot}59$ grammes for $P = 400$ atmospheres.

For each of the five experiments made, we will add the weight of oxygen corresponding to the diminution of pressure, observed at the moment of its again becoming stationary, to the weight of gas contained in the tube. The sum will represent the weight of liquid oxygen before the second jet issues.

*First Experiment.*—The initial pressure is 367 atmospheres. Formula (11) applied, gives for $F$:

$$F = \frac{0{\cdot}045467 \times 1{\cdot}437 \times 168 \times 367}{274} = 14{\cdot}705 \text{ grammes.}$$

On the other hand, we know that the pressure has gradually diminished from 367 to a stationary one of 308. The difference is 59 atmospheres.

The weight corresponding to this difference is

$$F = 0{\cdot}51517 \times 59 = 30{\cdot}395 \text{ grammes.}$$

The sum $F + F'$ = the weight of condensed oxygen.

$$F + F' = 45{\cdot}100 \text{ grammes.}$$

This experiment would give a value as the density of liquid oxygen:

$$\frac{45{\cdot}100}{45{\cdot}467} = 0{\cdot}9919.$$

*Second Experiment.*—The initial pressure is 395 atmospheres,

$F = 16{\cdot}21$ grammes.

The pressure descends gradually from 395 to 339 atmospheres, where it remains stationary. This is a difference of 56 atmospheres.

$F' = 0{\cdot}51517 \times 56 = 28{\cdot}85.$

$F + F' = 45{\cdot}06$ grammes.

The density $\frac{45{\cdot}06}{45{\cdot}467} = 0{\cdot}9908.$

*Third Experiment.*—The initial pressure is 432 atmospheres,

$F = 17{\cdot}306$ grammes.

The pressure falls to 378 atmospheres. The difference is 54 atmospheres.

$F' = 54 \times 0{\cdot}51517 = 27{\cdot}82$ grammes.

$F + F' = 45{\cdot}126$ grammes.

The density $\frac{45{\cdot}126}{45{\cdot}467} = 0{\cdot}9925$

*Fourth Experiment.*—The initial pressure is 400 atmospheres,

$F = 16{\cdot}59$ grammes.

The pressure falls to 346 atmospheres. The difference is 54 atmospheres.

$F' = 54 \times 0{\cdot}51517 = 27{\cdot}82$ grammes.

$F + F' = 44{\cdot}41$ grammes.

The density $\frac{44{\cdot}41}{45{\cdot}467} = 0{\cdot}9767.$

*Fifth Experiment.*—The initial pressure is 416 atmospheres,

$F = 16{\cdot}665$ grammes.

The pressure descends to 361 atmospheres, difference 55 atmospheres.

$F' = 55 \times 0{\cdot}51517 = 28{\cdot}33$ grammes.

$F + F' = 44{\cdot}995$ grammes.

The density $\frac{44{\cdot}995}{45{\cdot}467}$ 0·9896.

Taking a mean of the five experiments we will get a more exact result; and we find for the density

$d = 0{\cdot}9883.$

The first method we adopted gave us the value

$d = 0\ 9787.$

The difference 0·0096 may be classed with errors of observation. In fact, our manometer can only record pressures with accuracy to

within 1 atmosphere, and we have been obliged to use the specific heats beyond the limits of their experimental determination. The lowering of temperature during the experiments is a permanent cause of error, which tends to exaggerate the density.

Although having given the mean value of the density, deduced from the variations in pressure following the first jet during five experiments, we still think that the first method is more reliable, and furnishes a result that approaches nearer to reality. The number 0·9787, therefore, seems to us the most exact.

*Maximum Tension of the Vapors of Oxygen.*—The second physical element we intend to determine with exactitude, by means of the five recorded experiments, is the maximum tension of the vapors of oxygen. This determination is still very incomplete, as it demands a far greater number of experiments. It will be necessary to be able to cause the temperatures to vary between certain well-defined limits, and to observe the corresponding changes in pressure.

Our aim having been, principally, to liquefy the oxygen, we have utilized the minimum temperature attainable with our means. We made use of either carbonic acid, or protoxide of nitrogen, as an auxiliary liquid, and obtained, in consequence, two minima, one corresponding to each of the two liquids.

The numerical results contained in the table,[1] clearly show us the value of these two minima; one corresponding to the temperature of solid carbonic acid; the other, to that of the protoxide of nitrogen.

After the second liquid jet, during the first experiment, the pressure is still 285 atmospheres. This pressure falls gradually to the lower limit, 274, where it remains stationary and invariable during several minutes. This fall corresponds to a diminution of only 11 atmospheres. The weight of oxygen liquefied during the fall does not exceed 6 grammes. We are, consequently, certain that the condenser tube "is not full." Therefore, were the tension of the vapors of oxygen corresponding to the temperature of solid carbonic acid, less than 274 atmospheres, "condensation must continue;" but we see that it is arrested, consequently the maximum tension of the vapors of oxygen at this temperature is exactly 274 atmospheres.

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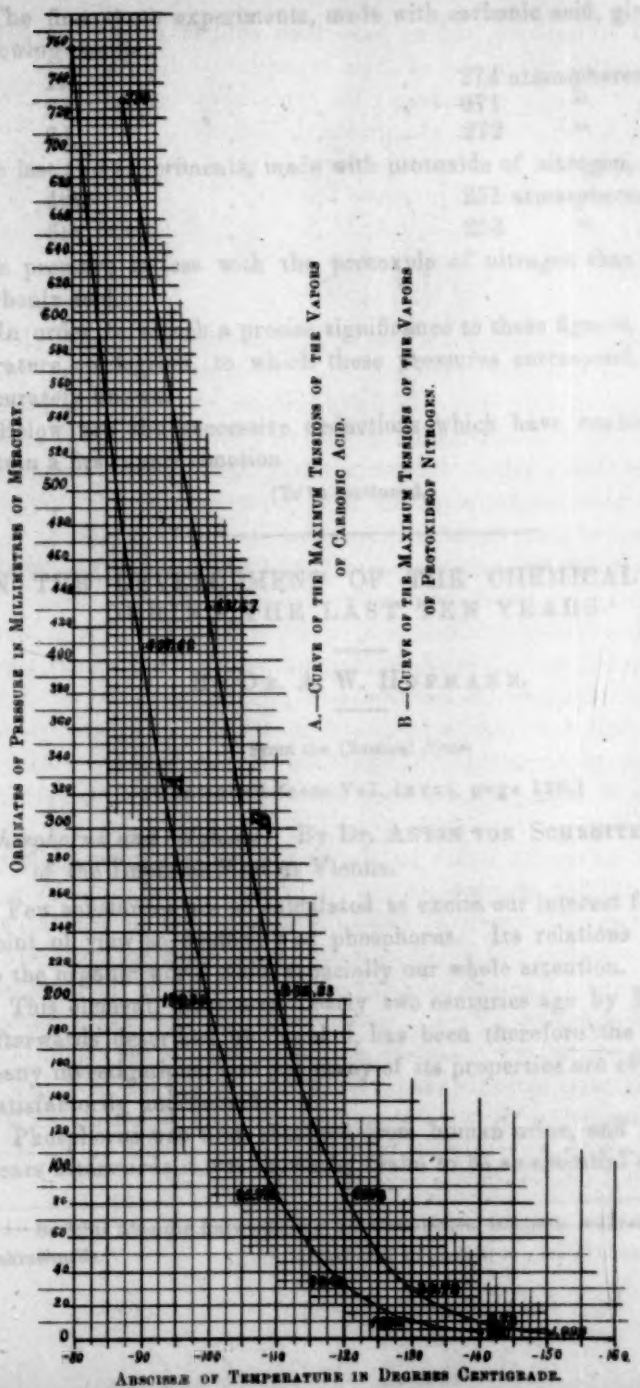
[1] See page 111 ant., at the end of last chapter.

PICTET'S EXPERIMENTS OF DECEMBER 22d, 1877. PLATE II.


ORDINATES OF PRESSURE IN MILLIMETRES OF MERCURY.
A.—CURVE OF THE MAXIMUM TENSIONS OF THE VAPORS OF CARBONIC ACID.
B.—CURVE OF THE MAXIMUM TENSIONS OF THE VAPORS OF PROTOXIDE OF NITROGEN.
ABSCISSÆ OF TEMPERATURE IN DEGREES CENTIGRADE.

The first three experiments, made with carbonic acid, give us the following results:

| | | |
|---|---|---|
| 1st, | 274 | atmospheres. |
| 2d, | 271 | " |
| 3d, | 272 | " |

The last two experiments, made with protoxide of nitrogen, give:

| | | |
|---|---|---|
| 4th, | 251 | atmospheres. |
| 5th, | 253 | " |

The pressure is less with the protoxide of nitrogen than with the carbonic acid.

In order to attach a precise significance to these figures, the temperature, in degrees, to which these pressures correspond, must be accurately known.

Below are the successive deductions which have enabled us to obtain a first approximation

(To be continued.)

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## ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. lxxvi, page 129.]

*Phosphorus and Matches.* By Dr. Anton von Schrötter, Master of the Imperial Mint at Vienna.

Few substances are so calculated to excite our interest from every point of view so decidedly as phosphorus. Its relations especially to the organic world claim especially our whole attention.

This element, discovered nearly two centuries ago by Brand and afterwards described by Kunkel, has been therefore the subject of many investigations, and yet many of its properties are even yet not satisfactorily understood.

Phosphorus was first obtained from human urine, and a hundred years afterwards it was shown by Gahn to be an essential constituent

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[1] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

of bones. From this fact its universal diffusion in nature might have been inferred, but it has been only of late demonstrated that not merely most substances found on the earth's surface contain phosphorus, but that it is present in most springs, in all rivers, in the sea, and even in the atmosphere (Barral), although but in slight traces. In fact, upon a soil free from compounds of phosphorus no plant could grow. In this respect, therefore, phosphorus ranks among the elements necessary for building up the vegetable and animal body, like oxygen, nitrogen, carbon, hydrogen, chlorine, sulphur, iron, calcium, etc.

Let us now, as far as our immediate purpose allows, consider the properties of phosphorus more closely.

The only kind of phosphorus which was known up to 1848, and which exclusively occurred in trade, and is still known as "ordinary," is a yellow translucent, and, when recently prepared and preserved from the action of light, perfectly limpid body, brittle at low temperatures, but assuming at 15° C. the consistence of wax. Notwithstanding this cerous consistence it still possesses a perfectly crystalline texture, as may be readily perceived by exposure for some time to the action of dilute nitric acid, which attacks it slightly, leaving a surface like that exhibited by tin after treatment with a dilute acid. The single crystals obtained from solvents are decidedly octahedra, exactly agreeing in appearance with common phosphorus, which may therefore justly be called the octahedral. Mitscherlich, however, has observed phosphorus crystallized in dodecahedra.

On exposure to a moist atmosphere phosphorus is luminous in the dark in consequence of a very gradual oxidation and formation of phosphorous acid, which gradually passes into the phosphoric. At the same time a small part of the uncombined oxygen is converted into the modification known as ozone.

The phosphoric vapors hereby diffused exert a very poisonous action if inhaled, producing a disease known as phosphorus necrosis, which begins with the disintegration of the jaw-bones and ends with their total destruction, and under which ill-fed and scrofulous persons sink with peculiar rapidity. Phosphorus introduced into the stomach acts as a violent poison.

With regard to its chemical behavior phosphorus must be placed in the same group of elements as nitrogen, arsenic, antimony, and perhaps some other of the simple bodies.

If preserved under water and exposed to daylight, ordinary phosphorus is covered with a white crust which gradually becomes detached. The nature of this body was for a long time doubtful. Baudrimont,[i] however, has shown that this crust is formed only under access of oxygen, and possesses all the attributes of ordinary phosphorus, whence we can scarcely doubt that it is merely common phosphorus which, assisted by the presence of the water, crumbles away from the sticks corroded by oxygen.

We may here also refer to the long-known, so-called black phosphorus, which, according to Thénard, may be obtained by rapidly cooling phosphorus—previously often distilled—an operation which, be it remarked, has never succeeded in the hands of the writer of this report. According to Blondlot[ii] phosphorus also becomes black when cooled slowly, but it must be perfectly pure and limpid. The black color is said to depend upon a black body, very minute traces of which are mixed with common phosphorus, which is left behind on solution in carbon bisulphide and passes over first on distillation, so that the last drops are colorless. Black phosphorus is rather softer than the ordinary kind, but is otherwise scarcely distinguishable. The nature of the black substance accompanying ordinary phosphorus, the formation of which is said to be promoted by mercury, though the latter element forms no part of its composition, is as yet unknown. It may be, as Blondlot supposes, a peculiar modification of phosphorus or a mere impurity.

Since 1848 an allotropic modification is met with in commerce under the name of *red*, or, preferably, as it is never a pure red and varies in color according to circumstances, *amorphous* phosphorus. This form differs from the octahedral phosphorus in its most important attributes in a degree almost as great as do the allotropic modifications of carbon—soot, graphite, and diamond—among themselves.[iii]

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[i] Baudrimont, *Comptes Rendus*, lxi, 857, 1866; *Zeitschr. f. Chem. N. F.*, ii, 31, 1866.

[ii] Blondlot, *Comptes Rendus*, lx, 830; *Gmelin Handbch. der Chemie* (Kraut's edition), i, Abth., 2, 103.

[iii] In the Official Report on Group III, Section 5, published by the General Direction of the Vienna Exhibition, occurs on p. 3 the following passage:—"Shortly after the non-poisonous and sparingly combustible red modification of phosphorus had been discovered *in Schrötter's laboratory*, etc." This passage, if it is to be conformable with the truth, should read: "Shortly after the non-poisonous modification of phosphorus had been discovered *by Schrötter*. I am therefore, after the lapse of twenty-seven years, once more compelled to explain that no one who at that time was work-

Amorphous phosphorus in compact pieces is an opaque reddish brown substance of imperfect metallic lustre, but where recently broken almost of an iron black. It is brittle, easily broken, and exhibits a perfectly conchoidal fracture with sharp edges. Its sp. gr. is 2·105; in hardness it lies between calcareous spar and fluor-spar. The color of the powder, and consequently of the streak, is reddish brown, exactly resembling that of ignited ferric oxide, otherwise known as colcothar.

Amorphous phosphorus is tasteless and inodorous, insoluble in all liquids which dissolve the octahedral variety, and consequently not poisonous. If taken into the stomach in considerable quantity it is excreted unchanged, and resists, therefore, the powerful oxidizing process in the animal body.

It is absolutely incapable of ignition by friction, and is therefore portable without danger. As the lumps, however, generally contain some ordinary phosphorus in small portions they have to be forwarded in water, since they might otherwise take fire if broken or rubbed. But even then the combustion proceeds very slowly. In the form of powder amorphous phosphorus may be conveyed in tin boxes without any danger.

As commonly met with in trade, the pulverulent amorphous phosphorus contains likewise small quantities of ordinary phosphorus—from 0·6 per cent downwards, according to Fresenius. It is therefore slowly oxidized on exposure to the air and has an acid reaction.

It has been also maintained that amorphous phosphorus, even in the absence of any intermixture of the ordinary variety, is slowly oxidized in the air. This is, however, doubtless an error, since the writer has preserved pure amorphous phosphorus for years, spread upon paper and freely exposed to the air without any trace of an acid reaction becoming perceptible. It is still, however, possible that there are circumstances, not yet ascertained, in which amorphous

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ing in my laboratory has a claim to any even mentionable share in this discovery. I observed the first facts relative to this matter in 1845, on which communications may be found in the *Reports of the Sessions of the Imperial Academy of Sciences of Vienna*, Bd. i, p. 25, and in the *Memoirs*, Bd. i, p. 1, and ii, 127. Also in the *Reports of Sessions*, Bd. i. p. 48; Bd. iv, p. 59, and p. 156. Other matter connected with this subject has been collated with historical accuracy in the "Reports by the Juries," Class ii, Sect. A. of the London Exhibition of 1862, drawn up by A. W. Hofmann. See art. "Phosphorus," p. 93.—A. v. S.

phosphorus, even in the absence of any admixture of the octahedral kind, may become acidified by the air. Such a behavior, though often occurring, by no means ranks among the normal attributes of this modification of phosphorus.

In addition to ordinary phosphorus and phosphorous acid, the amorphous phosphorus of commerce contains, inclusive of water, 4·622 per cent of other impurities, amongst which is always found graphite, derived from the iron vessels in which the preparation takes place.

For ignition amorphous phosphorus requires a temperature of at least 240°. In nitric acid it dissolves on account of its state of subdivision, far more readily than the common variety, because the latter, as a fused mass, offers a much smaller extent of surface for the attack of the acid. Chlorine which combines with common phosphorus with ignition has no action upon the amorphous modification. If heated in a rapid current of chlorine it burns with a yellow luminous flame.

The products of the reaction of various substances upon the two modifications of phosphorus are identical, a circumstance not observed in case of other elements occuring in allotropic forms; *e. g.*, carbon, according to the researches of Brodie, Berthelot, and Stingl.

The conversion of common phosphorus into the amorphous state is effected by exposure to light or to the prolonged action of a temperature of 240° to 250°. The transformation may be effected at 215°, but more slowly. At 260° re-conversion begins into ordinary phosphorus, the boiling-point of which, under average pressure, is about 290°. The transition from one allotropic state to the other can be more readily shown in the case of phosphorus than in that of any other element. All that is required is a glass tube closed with mercury and with several bulbs blown on its horizontal limb. Some common phosphorus is placed in the first bulb at the end of the tube, which on the application of heat ignites and consumes all the oxygen contained in the tube. The residue of the phosphorus is driven into the second bulb, converted there by cautious heating into the amorphous variety, and can then again be distilled into the third bulb in the state of ordinary phosphorus.

In 1865 Hittorf,[1] in a very valuable dissertation which essentially enlarged our knowledge of phosphorus, described a substance which he

[1] Hittorf, *Pogg. Ann.*, cxxvi, 193.

obtained on exposing amorphous phosphorus, together with lead, to a red heat in an exhausted glass tube. After cooling, black crystalline leaflets of a metallic lustre were found on the surface of the lead, and were regarded by Hittorf as phosphorus in a new allotropic modification, which he designated as the "metallic crystalline." It would be out of place to enter here upon a detailed examination of Hittorf's interesting observations, but mention must be made of the fact that common phosphorus exposed to temperatures exceeding 300° C. in closed vessels, and consequently exposed to considerable pressure, is transformed into the amorphous condition in a few minutes. As during this conversion a notable elevation of temperature takes place, the pressure upon the sides of the apparatus must be very great. Hittorf is of opinion that manufacturers engaged with the preparation of amorphous phosphorus will welcome such an abridgment of the process. The question, however, arises whether, in the treatment of large quantities, difficulties, and even dangers, might not arise far outweighing the economy of time. According to the present method, when the conversion is effected in open iron vessels in which the air finds but limited access, the process is more tedious, but free from all difficulty.

*Manufacture of Phosphorus.*—The bulk of the phosphorus is still prepared in the manner indicated by Nicolas and Pelletier. From the bone-earth $Ca_3(PO_4)_2$, is obtained the primary phosphate $CaH_4(PO_4)_2$, by treatment with sulphuric acid. This is converted by heat into calcium metaphosphate, $[Ca(PO_3)_2]$, and is then mixed with charcoal powder and distilled at a strong red heat.[1] Stoneware tubes are preferable to the retorts formerly in use, and care must be taken to allow the gases to escape unhindered so that there is no pressure to overcome. The importance of this in all cases where it is requisite to catch and condense vapors escaping from ignited earthen apparatus, will appear from the fact that not a trace of carbon bisulphide can be collected if its vapor has to overcome even a very slight pressure in earthenware apparatus.

The purification of crude phosphorus from impurities present in mechanical admixture, such as charcoal, etc., is best effected by forcing it at a slight pressure through leather by means of a Real's press, kept hot.

[1] For further particulars see article "Phosphorus," by A. W. Hofmann, in the already quoted "Report of the Jury on the London Exhibition of 1862."

The residue (re-generated calcium tri-phosphate) is an excellent clarifying agent, especially for glycerin, and is in great request for this purpose.

The conversion of ordinary phosphorus into the amorphous condition is effected in iron boilors heated to 240°, and left open, but so that the air finds scanty admission through a narrow and rather long tube. The danger of explosion is thus obviated and very little phosphorus is burned, since the interchange of air in the boiler takes place very slowly, whilst the phosphorus consumes all oxygen so rapidly, that within the boiler scarcely a trace of this gas is present. The amorphous phosphorus thus obtained, and still always retaining some of the ordinary modification, is ground under water, boiled with soda-lye to remove octahedral phosphorus, washed, and dried.

For the preparation of phosphorus, bone-earth, as already mentioned, is generally employed. It is, however, stated that, latterly, phosphorites have come into use for this purpose in England, a step which will be ultimately necessitated by the increasing demand for phosphorus, and by the other applications of bones. Already we are compelled to procure from very remote regions this precious and useful material, whose especial destination is to maintain, unbroken, the circulation of matter; which, of course, involves a sensible increase in the price.

It is, therefore, to be lamented that a large quantity of bones remain unutilized for this great purpose from indolence or ignorance, and another from deeply-rooted religious prejudices. Invitations and proposals to obviate these evils have not been wanting, and especially as regards the last mentioned point, they were to be found at the Exhibition. Thus Cav. Ludovico Brunetti, Professor of Pathological Anatomy at Padua, exhibited an apparatus for the incineration of dead bodies, together with the residue from the combustion of a corpse which had weighed 45 kilos. (No. 4149). The weight of the whitish residue was 1077 grms.; the process of combustion lasted three and a half hours, and the expense was merely 1·2 Austrian gulden.[1]

[1] See Brunetti's work "Cremazione dei Cadaveri;" also Dr. J. P. Trusen's "Die Leichenverbrennung als die geeignetste Art der Todtenbestallung," Breslau, 1855; and, finally, an excellent article by Sir Henry Thomson in the *Contemporary Review*, January, 1874, in which the subject is considered from the sanitary and economical points of view. (See *N. fr. Presse, F.*, 1874, No. 40). The best success must, therefore, be wished to the exertions of the recently-formed Cremation Society of Hamburg.

The quantity of bone-earth remaining on the incineration of bones varies according to age and to the part of the body to which they belong. On an average it is about 59 per cent. Its composition is:

| | |
|---|---|
| Calcium phosphate, $Ca_2(PO_4)_2$, . . . . | 85·7 |
| Magnesium phosphate, . . . . . | 1·7 |
| Calcium carbonate, . . . . . | 9·1 |
| Calcium fluoride, . . . . . | 3·0 |
| | 99.5 |

As, however, 100 kilos. of bones yield, at most, 8 kilos. of phosphorus, more than two-thirds of the total amount present in the bones remaining in the residues, it appears that for the production of the quantity of phosphorus required, a very considerable amount of bones is required, as shown in the following figures. R. Wagner states in his valuable "Yearly Report" (xi, 267), that in the year 1864 to 1865, the production of phosphorus was:—

| | Kilos. |
|---|---|
| In France and Italy, . . . . . | 100,000 |
| In Germany and Austria, . . . . | 90,000 |
| In England, . . . . . | 75,000 |
| | 265,000 |

for which 3,312,500 kilos. of bones were required. For the present time these figures are far too low, as will appear from the statistics of the French match trade, as given below.

Hence, it appears that in the preparation of phosphorus as generally carried on, a valuable material is consumed in a profligate manner. The endeavors of chemists to utilize it more thoroughly, are, therefore, still continued. On the one hand, the manufacture of animal charcoal or bone-black, an article of great importance in sugar-refining, and in many other branches of industry, has been greatly improved, the bones, previously freed from fat, being now heated, not in iron crucibles, but in horizontal cylinders, such as are used in the manufacture of coal-gas.[1] As by-products are obtained carbonate of ammonia, the consumption of which is daily on the increase, as also animal tar and a lighting-gas of very good quality.

[1] G. Lunge's description of the process of bone-distilling introduced in England. *Wagner Jahresber.* 1867, 199; *Dingl. Pol. Journ.*, clxxxiv, 513.

The tar is as yet a mere burden to the manufacturers, since it has not yet been brought into use, and is, therefore, disposed of by burning, which is not without difficulty. The time is, however, certainly not far distant when a product so rich in basic nitrogenous compounds will find a profitable utilization.

(To be continued.)

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## EDISON'S MICRO-TASIMETER.[1]

An important outgrowth of Mr. T. C. Edison's experiments with his carbon telephone transmitter, is an instrument for detecting minute changes of temperature, which, he claims, greatly surpasses the thermopile in delicacy.

In determining the thickness of carbon buttons best suited to the transmission of articulate sounds, he found that, within certain limits, increased thickness gave increased sensitiveness; but after using the instrument a short time it became inarticulate, and, finally, inoperative. An investigation showed that this was the result of expansion of the hard rubber handle by the heat of the hand.

This difficulty was soon overcome by a different mode of attaching the carbon button, but it had suggested a new use for its extreme sensitiveness.

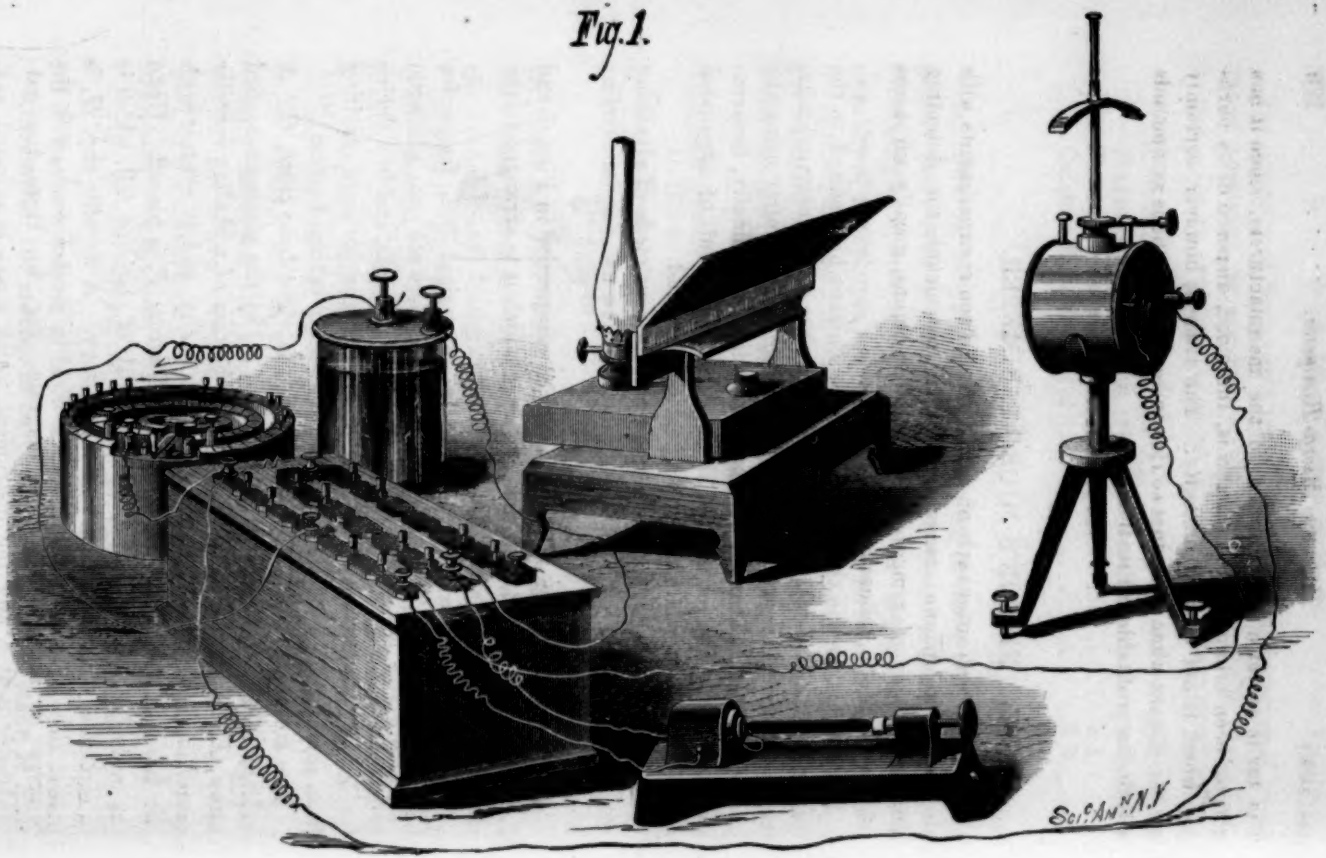
The micro-tasimeter is represented, in perspective in Figs. 1 and 2, in section in Fig. 3, and the plan upon which it is arranged in the electric circuit is shown in Fig. 4.

The instrument consists, essentially, in a rigid iron frame for holding the carbon button, which is placed between two platinum surfaces, one of which is fixed and the other movable, and in a device for holding the object to be tested, so that the pressure resulting from the expansion of the object acts upon the carbon button.

Two stout posts, *A*, *B*, project from the rigid base piece, *C*. A vulcanite disk, *D*, is secured to the post, *A*, by the platinum-headed screw, *E*, the head of which rests in the bottom of a shallow circular cavity in the centre of the disk. In this cavity, and in contact with the head of the screw, *E*, the carbon button, *F*, is placed. Upon the outer face of the button there is a disk of platinum foil, which is in electrical communication with the battery. A metallic cup, *G*, is placed in contact with the platinum disk, to receive one end of the strip of whatever material is employed to operate the instrument.

[1] We are indebted to Mr. Edison for the accompanying illustrations.

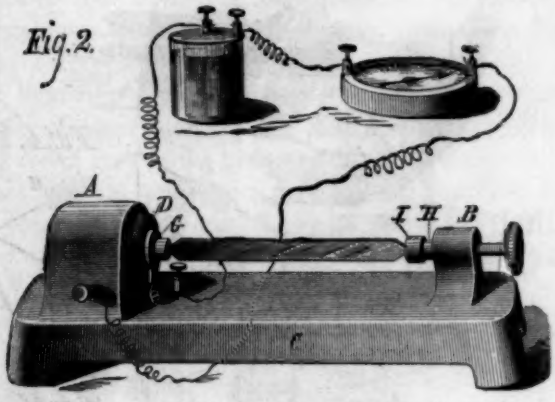
*Fig. 1.*




EDISON'S MICRO-TASIMETER.

The post *B* is about 4 inches from the post *A*, and contains a screw-acted follower, *H*, that carries a cup, *I*, between which and the cup *G* is placed a strip of any substance whose expansibility it is desired to exhibit. The post *A* is in electrical communication with a galvanometer, and the galvanometer is connected with the battery. The strip of the substance to be tested is put under a small initial pressure, which deflects the galvanometer-needle a few degrees from the neutral point. When the needle comes to rest, its position is noted. The slightest subsequent expansion or contraction of the strip will be indicated by the movements of the galvanometer-needle. A thin strip of hard rubber, placed in the instrument, exhibits extreme sensitiveness, being expanded by heat from the hand, so as to move through several degrees the needle of a very ordinary gal-

Fig. 2.



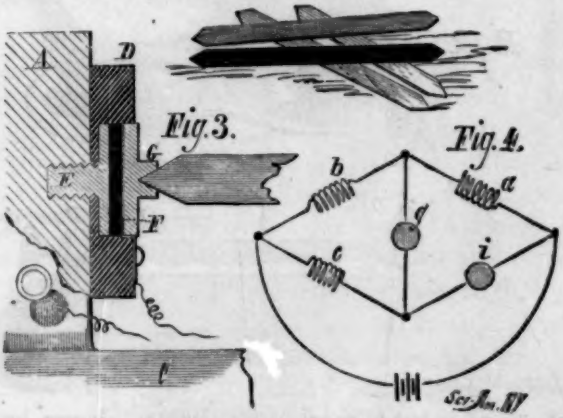

vanometer, which is not affected in the slightest degree by a thermo-pile facing and near a red-hot iron. The hand, in this experiment, is held a few inches from the rubber strip. A strip of mica is sensibly affected by the heat of the hand, and a strip of gelatin, placed in the instrument, is instantly expanded by moisture from a dampened piece of paper held 2 or 3 inches away.

For these experiments the instrument is arranged as in Fig. 2, but for more delicate operations it is connected with a Thomson's reflecting galvanometer, and the current is regulated by a Wheatstone's bridge and a rheostat, so that the resistance on both sides of the galvanometer is equal, and the light-pencil from the reflector falls on 0° of the scale. This arrangement is shown in Fig. 1, and the principle is illustrated by the diagram, Fig. 4. Here the galvanometer is at *g*, and the instrument which is at *i* is adjusted, say,

for example, in 10 ohms resistance. At *a*, *b* and *c*, the resistance is the same. An increase or diminution of the pressure on the carbon button by an infinitesimal expansion or contraction of the substance under test, is indicated on the scale of the galvanometer.

The carbon button may be compared to a valve, for, when it is compressed in the slightest degree, its electrical conductivity is increased, and when it is allowed to expand it partly loses its conducting power.

The heat from the hand, held 6 or 8 inches from a strip of vulcanite placed in the instrument—when arranged as last described—is sufficient to deflect the galvanometer-mirror so as to throw the light-beam completely off the scale. A cold body placed near the vulcanite strip will carry the light-beam in the opposite direction.




Mr. Edison proposes to make application of the principle of this instrument to numberless purposes, among which are delicate thermometers, barometers and hygrometers.

Speaking of this instrument, Mr. Edison says: "The heat-measurer was described and experiments shown to Professor Langley, the well-known astronomer of the Alleghany Observatory, some six months ago. On his suggestion, at the time, that it ought to be worked up as a very valuable boon to science, especially in the line he was investigating (that is, measuring the heat of the stellar spectra), I tried many experiments with it, and devised the form given. This apparatus was described to various members of the National Academy of Sciences, held at Washington, April 17th, 18th and 19th, 1878, and the Washington *Star* and *Union*, newspapers published then, gave a description of the instrument."

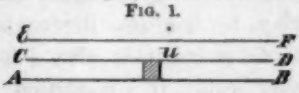
# NOTE ON THE POWER OF RUNNING WATER TO HOLD MATTERS IN SUSPENSION.

By J. P. Frizell, C. E.

Mr. Herschel has rendered an acceptable service by collecting the labors of engineers on this subject, performed at different times, and presenting them in one view. The following remarks are suggested by his recent articles in the Journal.[1]

M. Dupuit's theory, quoted by Mr. H., calls for a word of comment. The proposition, "Flowing water can hold bodies in suspension which are much more dense than it," is undisputed and indisputable. It may be also true that "the lower planes of the stream can carry more voluminous solids, or more of them, than those higher up," though not for the reason contemplated by M. Dupuit. As to the statement, however, which embodies the substance of his theory, viz., "The power of suspension depends upon the relative velocity of the filaments, and is greater the greater this relative velocity is," I hold that a more fanciful proposition was never reduced to writing. It may be observed, that this theory is more fully stated in the Humphrey's Abbott Report, p. 139, thus: "Dupuit demonstrates (Chapter V, "Etudes Théoriques et Pratiques sur le Mouvement des Eaux Courantes") that the power of suspension is due to the fact that the different layers of water are actuated by different velocities, and thus exert different pressures upon the different sides of the suspended atoms." "Hence," continues the report, "the greater the difference in the velocity of the consecutive layers, the greater will be the power of suspension."

Fig. 1.




Let us ask those who have adopted this theory, to reflect a little more seriously upon it. Let *A B*, *C D*, *E F*, Fig. 1, be horizontal planes indefinitely near each other, in a mass of water moving from *A* toward *B*, *C D* is moving a little faster than *A B*, *E F* a little faster than *C D*. Let *M* be a minute particle of sediment, clay, for instance, twice the specific gravity of water. The assumption is that the upward pressure of *A B* exceeds the downward pressure of *C D*,

[1] See vol. cv, p. 330.

by an amount equal to the difference between the weight of *M*, and an equal particle of water, on every element of the plane. Is this consistent with the commonest conception of the nature of force and motion? Force or pressure is *tendency to produce motion*. There can be no unbalanced pressure in a mass of water, without a corresponding motion. Strictly speaking, unbalanced pressure in a mass of water is impossible, because the slightest tendency that way instantly results in motion. Yet the theory only contemplates a horizontal movement from *A* toward *B*. It is, therefore, self-contradictory.

Again it is assumed, that, in virtue of the relative velocity of *C D* and *A B*, every element of the plane *A B* has the power of sustaining a particle of clay reaching from *A B* to *C D*, for if one element possesses this power, every other element must. The plane *C D*, also has, for the like reason, a similar power, with reference to the plane *E F*. Therefore, in virtue of the relative velocity between *E F* and *A B*, the latter plane has the power of bearing a stratum or lamina of clay reaching to the former; *i. e.*, the relative velocity being twice as great, the sustaining power is twice as great. Continuing this reasoning with reference to planes higher up, we reach the conclusion, that if M. Dupuit has demonstrated the power of water to carry, in accordance with this principle, a single particle of clay, he has also demonstrated its power to carry a block of limestone or coherent clay a foot in diameter. When we further reflect that water, in a condition to take up much sediment, does not move in parallel layers, or in anywise approaching thereto, we must admit that M. Dupuit's theory is a false deduction from erroneous premises. It is but the simulacrum of a simulacrum—the shadow of a shadow.

But the question still remains, Whence does water derive its power of sustaining matters denser than itself?

A spherical mass of indurated clay, 1 foot diameter, thrown into water 24 feet deep, will reach the bottom in less than three seconds.

A similar mass, $\frac{1}{100}$ of a foot in diameter, will require upwards of 25 seconds to reach the bottom. A finer subdivision will involve a slower rate of sinking, till, when reduced to impalpable dust, it may be 48 hours before the last particle reaches the bottom.

The cause of this is very obvious. The force which impels a body to sink, is its weight, which is proportional to the cube of its diameter. The force which resists sinking is the action of the water on the

cross-section of the body, being proportional to the square of the diameter. A diminution of the diameter reduces the sinking force in a greater ratio than the retarding force, and, consequently, diminishes the sinking velocity.

The velocity with which a spherical mass sinks, may be determined as follows:

Let $d$ be the diameter of the mass in feet.

$v$ the velocity in feet per second.

$\rho$ the specific gravity of the material.

The weight of the body is $0{\cdot}5236\ d^3\ \rho \times 62{\cdot}3$.

Its effective weight in water is $62{\cdot}3 \times 0{\cdot}5236\ d^3\ (\rho - 1)$.

The resistance of the water $= 0{\cdot}51 \times 62{\cdot}3 \times 0{\cdot}7854\ d^2 \frac{v^2}{2g}$ (see Rankine's "Applied Mechanics," p. 599).

When the velocity is uniform, the resistance is equal to the effective weight, and $0{\cdot}5236\ d\ (\rho - 1) = 0{\cdot}51 \times 0{\cdot}7854\ \frac{v^2}{2g}$; whence

$v = \sqrt{\frac{0{\cdot}5236\ d\ (\rho - 1)\ 2g}{0{\cdot}51 \times 0{\cdot}7854}}$. For the case of clay we may put $\rho = 2$

Putting $d = 1$, we have, for the velocity of a spherical mass of clay, 1 foot diameter, $v = 9{\cdot}17$ feet per second; for $d = \frac{1}{100}$, $v = 0{\cdot}917$ feet per second.

Putting $v = \frac{1}{7200}$, we have:

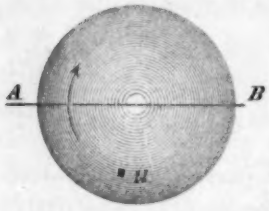
$d = \frac{0{\cdot}51 \times 0{\cdot}7854}{2g \times 0{\cdot}5236 \times (7200)^2} = 0{\cdot}000000000229$ foot, which is the diameter of a spherical particle of clay, capable of sinking at the rate of 6 inches an hour.

A solid particle heavier than water, and suspended therein, never ceases to sink with the full velocity determined by its size and specific gravity. Yet a particle, of appreciable size, may remain suspended long enough to travel great distances. In this respect, its slowness of sinking is aided by the internal movements of the water.

When water moves in an irregular channel, with a rapid fall, much of the mechanical energy due to the fall is wasted; that is, it does not contribute to the forward movement of the water, but expends itself, mainly, in gyratory movements around horizontal and vertical axes. The inequalities of a vertical wall along which water flows

lead to vertical eddies; those of the bed, to rotary movements around horizontal axes. These latter are most effective in the transportation of material. Consider how a particle of matter is affected by one of these whirls. Let *A B*, Fig. 2, be the horizontal line through the centre of such a whirl. The particle, *M*, participates in the whirling movement and, at the same time, obeys the action of gravity. The latter causes it to recede from the centre so long as it is below the line *A B*. When the whirling movement brings it above the line *A B*, the action of gravity causes it to approach the centre. Its movement thus consists of a series of oscillations, alternately approaching and receding from the centre, but making no progress toward the bottom. It is easy to conceive that a particle of gravel, capable of sinking in still water at the rate of 1 foot per second, may, while within the influence of a horizontal eddy, float as securely as a particle of sawdust. It escapes from one eddy only to fall within the influence of another. If it approaches the bottom, it may be sustained by one of those eddies till a more general gyratory movement lifts it into the higher regions of the stream, while the still more general movement of the current sweeps it forward.

Fig. 2.




The movements which take place in deep and rapid currents, flowing in irregular channels, are complex in the extreme: horizontal and vertical whirls, in which each particle of water has a velocity inversely proportional to its radius of gyration; movements in which each individual particle conforms to this law, while the general mass forms part of a greater whirl; wave movements proper, in which each particle tends to revolve around its position of rest with uniform angular velocity. In very deep water this tendency is fully realized, and the path is a circle of greater or less diameter at the surface, according to the magnitude of the disturbing cause, diminishing to nothing at the bottom. In shallower currents the movement is elliptical at the surface, and rectilinear at the bottom, All these movements, diversified by the form of the bed, are superposed upon and confounded with one another; and, with the general forward movement, in a manner to defy the most persistent faculty of analysis.

## THE GRAMME DYNAMO-ELECTRIC MACHINE FOR PRODUCING ALTERNATING CURRENTS.[1]

The recent improvement in the Jablochkoff system of electric illumination, and that which has given to it its present success, is the employment of an alternating current of electricity for establishing the electric arc between the carbon points. If the Jablochkoff candle[ii] is used with a continuous current, the positive carbon is consumed at twice the speed of the negative, but with a rapidly alternating current instead of a continuous one, the carbon will consume at an equal rate, each being alternately positive and negative to the other, and an alternating current possesses this further advantage, namely, that each stick of carbon is kept beautifully pointed instead of rough and irregular, and this symmetrical consumption of the carbonaceous matter is a great source of steadiness in the light.

The Jablochkoff candle may be used with advantage with any dynamo-electric machine which produces an alternating current, or by a continuous-current machine fitted with a commutator, by which the direction of its current is reversed every few seconds, but this arrangement for obtaining from a continuous-current machine a series of currents in alternate directions, can only be accompanied by great loss of electricity, and, therefore, of motive power, and it has been found much more economical and advantageous to use machines whose currents are originally generated in alternate directions. Of these, the machines of Holmes, of the Société l'Alliance, and of some others, would answer the purpose, but M. Gramme has designed a machine which is, to some extent, a modification of his previous arrangement, which not only produces an alternating current of electricity, but is capable of dividing that current, so as to supply electricity to four, six, sixteen, or more electric lamps, or candles. It is this new machine of M. Gramme which is now employed for producing the electric currents by which some 300 electric lamps are nightly illuminating the boulevards and public buildings of Paris.

This machine, the essential features of which are shown in the figure, consists of a ring of soft iron similar to that used in the earlier continuous-current machines of the same inventor. This ring

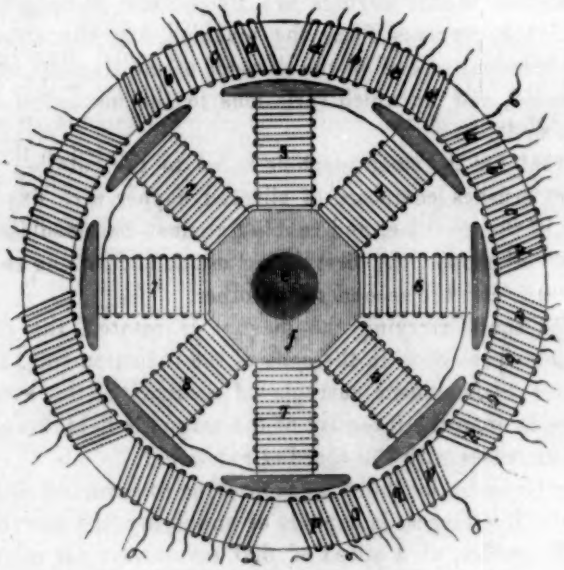
[1] Condensed from *Engineering*. The figure from sketch sent by Prof. E. Thomson.

[ii] See vol. civ, p. 142.

is, like its predecessors, wound with coils of insulated copper wire, but, unlike those of the earlier machines, the direction of winding is alternately right and left handed, the wire being wound in one direction, so as to cover one-eighth part of the circumference of the ring, then changing its direction, being wound in the contrary way over the next eighth part, and so on round the ring, each of the eight sections of the ring being wound in the reverse direction to that in which its two contiguous sections are wound. Thus, while the earlier Gramme ring might be described as an electro-magnet bent round in a circle and joined to itself, the ring of the new machine may be looked upon as eight curved electro-magnets placed end to end with their similar poles in contact, so as to form a circle. This ring is rigidly fixed in a vertical position to the solid framing of the apparatus, the inducting electro-magnets revolving within it. Here again it differs from the continuous-current machine in which the magnets were fixed, and the ring was rapidly rotated in the magnets fixed between their poles. The electro-magnets, of which there are eight, are fixed radially to a central boss, *f*, revolving upon a horizontal steel shaft, *e*, running in suitable bearings attached to the framing, and an external pulley enables the machine to be driven by a band from a steam-engine or other motor. The radial electro-magnets are alternately right and left handed in the direction in which their coils are wound, so that if they be numbered 1, 2, 3, 4, etc., up to 8, respectively, those represented by even numbers will have one polarity when a current is sent through them all together, while those whose numbers are uneven will have an opposite polarity. The poles farthest from the central boss, in all the magnets, are spread out so as to increase the area of the magnetic field by which electric currents are induced in the coils of the ring.

In the old machine of M. Gramme, the electro-magnets were excited by the current from a special Gramme ring mounted on the same shaft as the two rings which produced the available current, and the current from the first ring was exclusively devoted to exciting the electro-magnets. In further improvements upon his continuous-current machine, M. Gramme dispensed with an extra and special ring for charging the magnets, and devoted a portion of the current from a single ring to that purpose, two coils being wound on the same ring. In the present machine, however, there is no self-contained apparatus for

producing the current by which the electro-magnets are charged, although there is nothing to prevent an ordinary Gramme machine being attached to the same shaft. It is found more convenient, however, to use the new machine simply as an apparatus for dividing the current, and for giving to it a reciprocating nature, and, therefore, an altogether separate electro-motor is employed. An ordinary voltaic battery of sufficient power would answer the purpose, but in practice a small and separate Gramme machine of the continuous-current type is employed, driven by a separate strap, and the current from this machine being caused to traverse the coils of the rotating




radial electro-magnets, they are magnetized to saturation with but a small expenditure of motive power.

Each of the eight sections of the induction-ring are made up of four sub-sections, *a*, *b*, *c*, *d*, *a*, *b*, *c*, *d*, etc., all of which, in any one section, are wound in the same direction. By coupling the coils of these sub-sections in various ways, a division of the current may be made into 32, 16, 8, or only 4 circuits, and this is one of the most valuable qualities of the system.

From a consideration of the above description, it will be seen that all the sub-sections or coils marked *a* are influenced by the rotating

magnets in precisely the same manner, for the influence of a north pole upon a coil wound in a positive direction, is precisely the same as that of a south pole upon a coil wound in a negative direction, and similarly the currents induced in all the coils marked *b* are similar in direction to one another, no matter what may be the position of the rotating magnets. And in order to obtain four currents from the machine by which four lamps may be illuminated, all that is necessary is to connect together in series all the coils marked *a* for one circuit, all the coils marked *b* for a second circuit, all the coils marked *c* for a third circuit, and all the coils marked *d* for a fourth circuit. As the induction-rings are fixed, there is no difficulty in "tapping" the currents from the machine, and the apparatus is fitted with terminal screws on the exterior of the rings by which that can be effected, and by which variations in the method of coupling up may be made.

The current for the small machine is led to the rotating magnets through flat brushes composed of silvered copper wire fixed to the framework of the machine, and rubbing against two insulated drums or cylinders of copper, the first being connected to one end of the magnet-circuit, and the second to the other.

When the shaft carrying the magnet is rotated, the expanded magnetic poles pass close to the coils of the induction-ring, and in so doing induce within them currents of electricity, the strength of which depends upon the intensity of the magnetic field brought over them, and increases with the speed of rotation.

The new Gramme machine, as at present constructed, is made in three sizes. The largest is capable of supplying the current to 16 Jablochkoff candles, at a speed of 600 revolutions per minute, and absorbing a motive power of about 16 horse-power, costs, with the smaller machines for charging the magnets, 10,000 francs (= £400), its length, including the shaft and pulley, is 35 in., its width 30 in., and its height about the same; the total weight is a little over 12½ cwt. The second size machine requires 6 horse-power to drive it, at a speed of 700 revolutions per minute, and supplies the light to 6 Jablochkoff candles, and costs with its small machine, 5000 francs (£200). It measures 27 in. in length, 15 in. in width, and 20 in. in height, and weighs rather over 5 cwt. The smallest size actuates, at a speed of 800 revolutions per minute, 4 Jablochkoff lights, and

absorbs 4 horse-power of motive power. Its dimensions are as follows: Length, 21 in; width, 15 in.; height, 18 in.; and its total weight is about 3½ cwt. In addition to these three sizes, M. Gramme has a new machine in hand, which differs in construction, in several material points, from those to which we have referred, and from which he hopes to effect a saving in both the prime cost and the cost of working the machine. It is designed for use with 2 Jablochkoff candles.

It will be seen from the above figures that the power absorbed is almost exactly 1 horse-power for each candle, and the results of a year's working of the system at the Hotel and Magazins du Louvre, very closely supports that estimate.

That M. Jablochkoff has solved the problem of producing a steady electric light, requiring but little attention, and suitable for street illumination of a very beautiful order, must be self-evident to all visitors to Paris at the present time.

Whether the system, however, is a success in an economical and commercial point of view, is another question altogether, and remains to be proved. We are rather inclined to the opinion that in its present stage it is rather costly, although light for light it will compare favorably with gas.

The whole system, much as it adds to the beauty and attractions of the city of Paris, must still be looked upon as in its childhood; it is rather more than a step, it is a long stride in the right direction, and we cannot but believe that further improvements, both in the construction of the machines for generating the electrical currents, and in the apparatus for converting those currents into centres of illumination, will burst through all obstructions placed in its path.

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**Absorption of Carbonic Oxide by Living Organisms.**—N. Gréhaut has experimented with mixtures of air and minute portions of carbonic oxide. He finds that a man or an animal, when compelled for a half-hour to breathe an atmosphere containing only $\frac{1}{779}$ of carbonic oxide, absorbs that gas in sufficient quantities to saturate about half of the red globules of the blood, so that they become incapable of absorbing oxygen. In an atmosphere containing $\frac{1}{1449}$ of carbonic oxide, about a quarter of the red globules are similarly saturated. These results are interesting and important in relation to physiology and hygiene.—*Comptes Rendus.* C.

# DESCRIPTION OF A MONTGOLFIER RAM BUILT BY THE I. P. MORRIS COMPANY, PHILADELPHIA.

By Washington Jones.

Recently, the I. P. Morris Company made at their Port Richmond iron works, to be used for the purpose of irrigating the higher lands of a coffee plantation in South America, a hydraulic ram, whose capacity is greater than that of any other known to them. The following data were furnished by the purchaser with his order. As will be noticed, they cover the most important points, except the quantity of water available, which, therefore, was assumed to be ample:

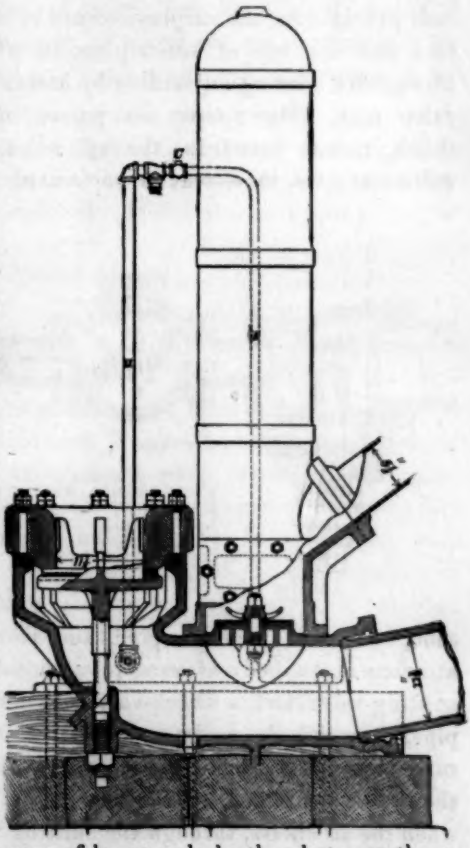
| | |
|---|---|
| Height of fall, | 9 ft. 10 in. |
| Elevation of reservoir, | 63 " 10 " |
| Diameter of inlet-pipe, | 11½ " |
| Length " " | 52 " 4 " |
| Diameter of ascension-pipe, | 5½ " |
| Length " " " | 127 " 8 " |
| Diameter of waste-valve, | 11½ " |
| Contents of air-vessel, | $4\frac{2}{10}$ cu. ft. |

The capacity of the air-vessel was increased to 5½ cu. ft., as the additional expense of the material was amply compensated by the known advantage of a large air-cushion, in partially relieving this type of machine from the violent shocks inseparable from its action. The minor details, and their disposition, were determined upon by the constructors, after consideration and information obtained by reference to Crecy, London *Engineer*, and Spon's "Dictionary of Engineering," wherein were found descriptions of several which, though of small capacity, were of assistance in forming a conclusion. The results were embodied in the machine, of which the following is a description. A reference to the cut will make the construction more readily understood:

The body of the ram is a cylindrical pipe 11½ inches bore and 1⅛ inches thick, strengthened with flanges. It curves upwards, at the rear or discharge end, until the axis of bore becomes vertical, when the bore is enlarged to 19½ inches, so as to form a chamber for the waste-valve. Several vertical ribs join the flange, provided for the valve-seat at top of chamber, with the main body of the ram. About

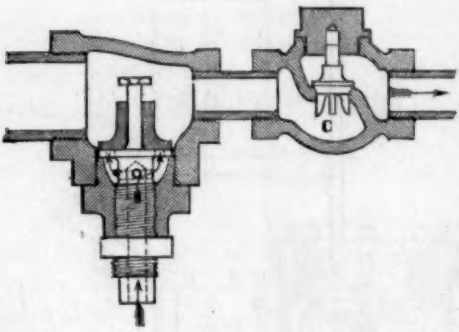
midway the length of the body is the seat for water-valve and the air-vessel. A horizontal flange on each side of body, strongly ribbed, serves to hold the machine to timbers which rest upon stone foundations. Six bolts pass through all, with keys and plates at lower ends. The water-valve is of gum, and seats upon a grating cast on the body of ram, and is held in position by a stud carrying a guard. This valve is encased by the air-vessel, and access to it is had through a door. The body of the waste-valve is of cast iron, strongly ribbed, and is guided, at its upper end, by wings sliding within the bore of valve-seat, and, at its lower end, by a stem working in a hole bored in the body of ram. This hole is fitted, at its lower end, with a long tap-bolt, which is used to adjust the drop of the valve and the number of beats per minute at such a point, found by trial, where best efficiency of ram is obtained. A piece of gum, interposed between the ends of stem and tap-bolt, serves to soften the blow of descending valve. The face of waste-valve is a ring of wrought iron, riveted to the valve with three thicknesses of heavy sole-leather between them, so as to give some elasticity, and thereby diminish the shocks given by the valve closing. The waste-valve seat is of cast iron, made heavy (about five times the weight of the valve), and firmly bolted to the body of ram. The supply is carried through cast iron pipes having socket-joints, and their thickness diminishes from $1\frac{1}{8}$ inches at the junction with ram, to $\frac{5}{8}$ inch at the upper end. The ascension-

Fig. 1.



pipe is welded wrought iron tube, 5½ inches diameter, joined by flanges. The apparatus for supplying air to the air-vessel, is essentially that designed by Mr. Bolèe (see Spon's "Dictionary of Engineering," article "Hydraulic Machines," folio 1972), with a modification of the "snifting-valve," which compels all the air admitted through it to enter the air-vessel; or if in excess, as in this case provided so, the surplus escapes between the under side of valve-seat and the top of screw-plug, on which the valve is mounted, through an opening adjustable by means of the screwed shank of the valve seat. The supply air passes upwards through the hollow shank, thence outwards, through holes, into the space below the valve-seat; the valve-seat is perforated with several holes, through which the air rises and lifts the valve. When the valve closes, the return of any air is prevented, but if the seat be raised from the top of the plug, a portion of it, more or less, as desired, passes between them and escapes (see enlarged view of snifting-valve). The valve is placed high enough to be above floods, and its operation is as follows: The tube, *a*, is of 1 inch gas-pipe, and it rises, from the point of its attachment to body of ram, to a suitable height, and carries the snifting-valve and a check-valve; it is then joined by a ½ inch gas-pipe, *b*, which descends and meets a check-valve, attached to the ram, immediately under the air-vessel. When the waste-valve opens, the water contained in the pipe, *a*, falls, and produces a vacuum, when the air enters, through the snifting-valve, into pipe *a*. When the stroke recurs and waste-valve closes, the water rises in pipe *a*, and displaces the air, which, under pressure, opens the check-valve *c*, whence it passes, through pipe *b* and check-valve *d*, into body of ram, and ascends into the air-vessel. This occurs each stroke, so that supply of air is continuous. Any surplus is discharged by the modification before described.

Fig. 2.



Upon completion the apparatus was set up in position, and pipes attached; about 35 feet of ascension-pipe, placed vertically, and 48 feet of supply-pipe, connected with a tank holding enough water for five minutes run, set 10 feet high (or the height of fall) above ram. Short trials were made, mainly to prove the work, and, if possible, to get adjustment of waste-valve, giving best results as to quantity of water raised with least hammer of valve, but the limited supply of water, and the temporary manner in which the arrangements were obliged to be made, prevented any rigid tests, and, consequently, no results of value were obtained.

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## AERIAL ECHOES.[1]

By JOSEPH HENRY.

During the year 1877, and also in 1876, a series of experiments was made on the aerial echo, in which I was assisted in the first series by General Woodruff, engineer of the third lighthouse district, and in the second series by Edward Woodruff, assistant engineer of the same district. These experiments were made principally at Block Island, but also at Little Gull Island. Especial attention has been given to this phenomenon, which consists in a distinct echo from the verge of the horizon in the direction of the prolongation of the axis of the trumpet of the siren, because the study of it has been considered to offer the easiest access to the solution of the question as to the cause of all the abnormal phenomena of sound, and also because it is in itself an object of much scientific interest.

In my previous notice of this phenomenon, in the report of the Lighthouse Board for 1874, I suggested that it might be due to the reflection from the crests of the waves of the ocean; but as the phenomenon has been observed during all conditions of the surface of the water, this explanation is not tenable.

Another hypothesis has been suggested, that it is due to a flocculent condition of the atmosphere, or to an acoustic invisible cloud, of a density in different parts differing from that of the general atmosphere at the time. To test this hypothesis experimentally, the large

[1] From report of the Lighthouse Board, 1877.

trumpet of the siren was gradually elevated from its usual horizontal position to a vertical one. In conception, this experiment appears very simple, but, on account of the great weight of the trumpet, it required the labor of several men for two days to complete the arrangements necessary to the desired end. The trumpet, in its vertical position, was sounded at intervals for two days, but in no instance was an echo heard from the zenith, but one was in every case produced from the entire horizon. The echo appeared to be somewhat louder from the land portion of the circle of the horizon than from that of the water. On restoring the trumpet to its horizontal position, the echo gradually increased on the side of the water, until the horizontal position was reached, when the echo, as usual, appeared to proceed from an angle of about twenty degrees of the horizon, the middle of which was in the prolongation of the axis of the trumpet. A similar experiment was made with one of the trumpets of the two sirens at Little Gull Island. In this case the trumpet was sounded in a vertical position every day for a week with the same result. On one occasion it happened that a small cloud passed directly over the island on which the lighthouse is erected, and threw down on it a few drops of rain. At the moment of the passage of this cloud the trumpet was sounded, but no echo was produced.

From these experiments it is evident that the phenomenon is in some way connected with the horizon, and that during the continuance of the experiment of sounding the trumpets while directed toward the zenith, no acoustic cloud capable of producing reflection of sound existed in the atmosphere above them.

Another method of investigating this phenomenon occurred to me, which consisted in observing the effects produced on the ears of the observer by approaching the origin of the echo. For this purpose, during the sounding of the usual interval of twenty seconds of the large trumpet at Block Island, observations were made from a steamer, which proceeded from the station into the region of the echo, and in the line of the prolongation of the axis of the trumpet, with the following results:

1. As the steamer advanced, and the distance from the trumpet was increased, the loudness of the echo diminished, contrary to the effect of an echo from a plane surface, since in the latter case the echo would have increased in loudness as the reflecting surface was

approached, because the whole distance traveled by the sound-wave to and from the reflector would have been lessened. The effect, however, is in accordance with the supposition that the echo is a multiple sound, the several parts of which proceed from different points at different distances of the space in front of the trumpet, and that as the steamer advances toward the verge of the horizon, it leaves behind it a number of the points from which the louder ones proceed, and thus the effect upon the ear is diminished as the distance from the trumpet is increased.

2. The duration of the echo was manifestly increased, in one instance, from five seconds, as heard at the mouth of the trumpet, to twenty seconds.

This would also indicate that the echo is a multiple reaction of varying intensities from different points, and that at the place of the steamer the fainter ones from a greater distance would be heard, which would be inaudible near the trumpet.

3. The arc of the horizon from which the echo appeared to come was also increased, in some cases, to more than three times that subtended by the echo at the place of the trumpet. This fact again indicates that the echo consists of multiple sounds from various points at or near the surface of the sea, the angle which the aggregate of these points subtend necessarily becoming greater as the steamer advances.

But perhaps the most important facts in regard to the echo are those derived from the series of observations made in regard to it by Mr. Henry W. Clarke, the intelligent keeper of the principal lighthouse station on Block Island, and by Joseph Whaley, keeper of the Point Judith Lighthouse. Mr. Clark was furnished with a time-marker to observe the duration of the echo, and both were directed to sound the trumpets every Monday morning for half an hour, noting the temperature, the height of the barometer, the state of the weather as to clearness or fog, the direction and intensity of the wind, and the surface of the ocean.

From the observations made at these two points, for more than two years at one station, and over a year at the other, the echo may be considered as produced constantly under all conditions of weather, even during dense fogs, since at Block Island it was heard 106 times out of 113, and at Point Judith 50 times out of 57, and on the occasions when it was not heard the wind was blowing a gale, making a noise

sufficiently intense to drown the sound of the echo. These results appear to be sufficient to disprove the hypothesis that the phenomenon is produced by an acoustic cloud accidentally situated in the prolongation of the axis of the trumpet. It must be due to something more permanent in its effects than that from a portion of air differing from that of the general atmosphere in temperature or density, since such a condition cannot exist in a dense fog embracing all the region of the locality of the phenomenon. Indeed, it is difficult to conceive how the results can be produced, even in a single instance, from a flocculent portion of atmosphere in the prolongation of the axis of the trumpet, since a series of patches of clouds of different temperature and densities would tend to absorb or stifle by repeated reflections a sound coming from their interior rather than to transmit it to the ear of the observer.

The question, therefore, remains to be answered: What is the cause of the aerial echo? As I have stated, it must in some way be connected with the horizon. The only explanation which suggests itself to me at present is, that the spread of the sound which fills the whole atmosphere from the zenith to the horizon with sound-waves may continue their curvilinear direction until they strike the surface of the water at such an angle and direction as to be reflected back to the ear of the observer. In this case the echo would be heard from a perfectly flat surface of water, and as different sound-rays would reach the water at different distances and from different azimuths, they would produce the prolonged character of the echo and its angular extent along the horizon.

While we do not advance this hypothesis as a final solution of the question, we shall provisionally adopt it as a means of suggesting further experiments in regard to this perplexing question at another season.

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**Gnomonic Projection.**—In presenting De Chancourtois's gnomonic atlas to the academy, Faye called attention to the advantage which the gnomonic projection possesses in representing the great circles of the sphere by simple, straight lines. Chancourtois employs a projection upon the eight faces of an octahedron, and Faye considers his method peculiarly desirable for geographical, geological, and lunar maps.—*Comptes Rendus.* C.

## RAILWAY BRAKES.

A very interesting and important series of experiments, for the purpose of determining the degree of force with which it is desirable that brake-blocks should be pressed upon the wheels of a train, has recently been conducted upon the London, Brighton and South-Coast Railway, under the supervision of Captain Douglas Galton, C. B., F. R. S., and of Mr. Westinghouse.

Although continuous brakes have now been in use for many years, there have, hitherto, been no data for arriving at any certain conclusion with regard to the force with which they should be applied to produce the best results; and the widest differences of opinion, or rather of conjecture, have prevailed upon the subject. It has even been uncertain whether brakes were more effectual when the wheels were skidded and suffered to slide along the rails, or when the blocks were applied with a force just short of that by which skidding would be produced. It will be remembered that at the trials at Newark in 1875, conducted under the control of the Royal Commission on Railway Accidents, a crude attempt was made to determine the difference between the effects of skidding and of merely impeding rotation; and it was supposed from this attempt that skidding was most to be desired. On the other hand, at the series of trials conducted last year at Cassel, the German railway engineers started with the hypothesis that a brake-block pressure equal to only one-half the weight of the wheels upon the rail would produce the best results; while in this country the general practice has been to arrange the pressure to be slightly in excess of the weight of the wheels. For the determination of the various points at issue, the experiments to which we refer were commenced on the Brighton line in May; and, certain preliminary information having thus been gained, they were recently recommenced on a larger and more important scale, and were continued for four days. A special four-wheeled van, built by Mr. Stroudley, the locomotive superintendent of the line, was placed at the disposal of Mr. Westinghouse, who designed the whole of the apparatus employed for the purpose of measuring and recording the various facts which were to be determined. These facts were: first, the amount of friction between the brake-blocks and the wheels at various speeds; second, the force with which the brake-blocks were being pressed against the wheels, shortly described as "brake-block

pressure;" and third, the retarding effect of the brakes, as shown by the strain upon the draw-bar.

The brake-blocks of the front pair of wheels of the van were suspended from the ends of two levers, which were arranged to press against the piston of a hydraulic cylinder. When the blocks were pressed against the revolving wheels, the friction between the wheels and the blocks caused the levers to turn upon their centres, and thus produced a corresponding pressure in the cylinder. This pressure was recorded by an ordinary Richards' steam-indicator, the arm of which was turned by a simple water-clock while the brakes were in action. There was also a hydraulic cylinder with an indicator to record the force with which the brake-blocks were pressed against the wheels; another to measure the strain upon the draw-bar; another to record the weight resting upon the wheels; and two of Mr. Westinghouse's speed-indicators to record separately the speed of the two pairs of wheels. Two of Mr. Stroudley's speed-indicators were also used, to facilitate the observations. The drums of all the indicators were driven by the one water-clock already mentioned, and hence the diagrams were all of the same length. Brakes were attached to operate upon both pairs of wheels when required, but in many of the experiments the blocks were only applied to the wheels which carried the recording apparatus. The van was fitted with the cylinder, reservoir, triple valve, and pipes of the Westinghouse automatic brake; and was provided with gauges and cocks by means of which the blocks could be applied with any desired degree of force. The van was drawn by the fine locomotive "Grosvenor," which also was fitted with the usual Westinghouse brake appliances, and the experiments were conducted during the course of repeated trips backwards and forward on the line between Brighton and Hastings.

The first series of experiments was directed to ascertain the exact amount of force required to skid the wheel at various rates of speed, and the retarding effect which was obtained before and after skidding occurred. When the van had attained the desired speed, the brakes were gradually applied to one pair of wheels with an increasing force until skidding was produced. At the same time with the first application of the brake the water-clock was started, and diagrams indicating the various forces and speeds were taken in the manner already referred to. These experiments were tried with the van running at speeds ranging from less than 1 mile to over 60 miles an

hour. Many days will be required in order fully and carefully to work out and analyse the results shown by the very numerous diagrams which were obtained; and we can only give an approximately correct statement of some of the more important facts which were clearly demonstrated. When the van was barely moving the pressure required to skid the wheels was about equal to the weight of the braked wheels upon the rail; while at 60 miles an hour, with more than three times this amount of brake force, no skidding could be obtained, and, at 50 miles an hour, the last stated amount was barely sufficient for the purpose. Just before the occurrence of skidding, the retarding force was in many cases equal to nearly 20 per cent. of the load upon the wheels; but, as soon as the wheels were skidded, this retarding force was suddenly reduced to less than 3 per cent. at high speeds, the retarding effect of the skidded wheels gradually increasing as the the speed diminished and again reaching nearly 20 per cent. at the moment of coming to rest. The result of this series was clearly to demonstrate the necessity of the application of a very high degree of brake force when running at high speeds, and also to show that this degree of force should be gradually relaxed and diminished in proportion as the train speed itself is diminished by the pressure. It was also clearly proved that skidding must be absolutely avoided, especially at high speeds, if the best results are to be obtained.

After fully 100 experiments of this kind had been made, it was determined to enter upon a second series, in order to ascertain the practical usefulness of the knowledge which had been gained. For this purpose the brakes of the van were so arranged as to go on automatically at the moment when the van was detached from the engine by means of a slip coupling. In most of these experiments the blocks were adjusted to apply themselves to both pairs of wheels, so that the entire weight of the van might be used in stopping. Two whole days, the 24th and 25th, were occupied with these slip experiments, but it was only on the 25th that the times and distances were taken with absolute accuracy. Nine of the experiments on the 25th were made when running at 50 miles an hour, and were with various degrees of brake pressure, commencing with a degree equal to half the weight of the van upon the rails, and rising to one which produced skidding almost immediately. Two were made at about 60 miles an hour, five at about 50 miles, and two at about 30 miles; the pressure exerted being varied at each stop. For the purpose of reducing the

brake power as the speed slackened, a pressure-reducing valve was put in connection with the brake cylinder by M. Westinghouse, and was so arranged that the brake might be used either with the valve or without. The practical value of this valve was very clearly shown in experiments 18 and 19, both of which were conducted upon level rails.

In experiment 18, with a speed of 50 miles an hour and a constant brake-pressure equal to 156 per cent. of the weight of the van upon the rails, both pairs of wheels were skidded in 1 and 1½ seconds respectively, or as soon as the speed was reduced to 46 miles per hour; 27 seconds and 308 yards were required to make the stop.

In experiment 19, with the reducing valve open, and with a maximum brake-pressure of 144 per cent., skidding of the hinder pair of wheels was altogether avoided, and skidding of the leading pair, to which the recording apparatus was applied, did not occur until the speed had been reduced from 50 to 42½ miles an hour. Only 15¾ seconds and only 180 yards were required to make the stop.

In experiment 17, the pressure was 164 per cent., and caused the skidding of both pairs of wheels almost instantly. The speed was 50 miles; and 315 yards and 27¼ seconds were required to stop the van; while in No. 21, in which the brake-pressure, originally of 102 per cent., was kept below the skidding point by the reducing valve, the van was stopped in 149 yards and in 11¾ seconds. In other words, when the wheels were skidded all the time, nearly twice the distance was required to effect a stop from a speed of 50 miles an hour that was required when the pressure was kept just short of the skidding point. In the last-mentioned experiments, as in the two preceding ones, the van was running on level rails. In all, the brake apparatus was so arranged as to give an almost instantaneous application of the maximum force; and, although this force was sometimes very great, no inconvenience or shock was felt by any of the occupants of the van until skidding was produced, while in all cases the stops were remarkably smooth.

Seven experiments were made with wrought-iron brake-blocks in order to determine their comparative merits. The friction appeared to be about the same as that produced by cast-iron blocks; but the tires were torn, and great sparks of fire were thrown up while the wrought-iron blocks were in action. At the moment of skidding with wrought iron, the shock was tremendous and even dangerous.

On examination of the blocks, it appeared that their grip upon the wheels had torn small pieces out of the treads, and had stopped the rotation much more suddenly than cast-iron blocks would have done. The wrought blocks, in a very short time, wore and roughened the tires perceptibly; while the action of cast blocks left the tires quite smooth.

The experiments above described have therefore sufficed to determine the relative values of skidded and of merely retarded wheels as means of stopping a train, and also to determine the relative merits of cast and of wrought iron as materials for brake-blocks. It will be easy to ascertain, by a further series, whether the powers of the various continuous brakes now in use are sufficient to produce good results; and it is proposed by Captain Douglas Galton, who has taken up the question as one of scientific mechanics, to institute trials of the several brakes now before the public, and to use the experimental van for the purpose of accurately recording the results. If the co-operation of the various railway companies can be obtained, the suggestion is to fit the cylinders and pipes of the different continuous brakes to the van, and to arrange the levers to exert the same force that will be exerted by the brake-blocks on the other wheels of the train. The van will be placed successively in front, in the middle, and at the rear of the train; and the recording apparatus will be started by electricity at the moment of the application of the brakes. In this manner correct diagrams will be obtained, recording the amount of brake power, the length of time required to bring the full amount of this power to bear, the actual speed of the train at all points during the stop, and the rate of retardation. The experiments would be tried also under three conditions—1. With the brake-blocks properly adjusted for prompt action, as in a train in perfect order. 2. With each brake-block half an inch from its wheel, as in trains in ordinary condition. And, finally, with each block three-quarters of an inch from its wheel, as in trains in bad condition. A fourth series of trials is also contemplated, in order to show, even to the most casual observer, the relative values in action of different continuous brakes. It is proposed to run competing trains side by side, on parallel lines, and to apply the brakes to each at the same moment. The conditions will necessarily be the same for each, and the respective merits most at once declare themselves.

It is to be regretted that Captain Galton and Mr. Westinghouse did not avail themselves of the opportunities afforded by their slip experiments to arrange the brakes in such a manner that their maximum force should be applied to the wheels first in one second of time, then in two seconds, then in three, and so on until the period of 12 seconds had been reached, that being the time which is required by some of the continuous brakes now in use before they can be brought to bear over the whole length of a train. The whole of the experiments so far have been conducted with the Westinghouse automatic brake, and they have shown its power to any pressure which may be required, and also to give instantly a very high pressure, which is capable of being gradually reduced, when necessary, by the action of the reducing valve.—*The (London) Times.*

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**Internal Heat of Rocks.**—Daubrée reports some experiments upon the heat which may be developed by mechanical action in the interior of rocks, especially in clays, and applies his results to the theory of metamorphism. He finds that the heat increases much more rapidly when the mass is tenacious than when it is plastic, the particles in the latter case being, as it were, lubricated and slipping over one another. The experiments may, perhaps, also have an important bearing upon Mallet's theory of earthquakes and volcanoes. —*Comptes Rendus.* C.

**Variations of Weight.**—Plantamour has made a recent communication to the French Academy, upon the changes which are observed in the directions of vertical lines at any given place. Similar observations have been previously made by Bouquet de la Grye, with the seismograph, and by d'Abbadie, with the aid of the "nadirane." The latter thinks that the variations of the plumb-line can result only from two causes: either from a change of position in the earth's centre of gravity, or from a movement of the superficial layers of the ground. It seems likely, however, that a variety of influences may be at work, some acting vertically, some tangentially, and some in intermediate directions. In order to study the phenomena properly, it is necessary to combine the aberrations of the seismograph and of the "nadirane" with a continuous registry of the intensity of the weight.—*Les Mondes.* C.

**Almaden Mines.**—The amount of quicksilver which has been yielded by the Almaden mines during the past three centuries, is 120,179·6 tons, viz.: From 1564 to 1700, 17,863·72 tons; from 1700 to 1800, 42,149·501 tons; and from 1800 to 1875, 60,166·379 tons. At the rate of 12 fr. per kilogramme, the total value would be 1,440,000,000 fr.—*Ann. des Mines.* C.

**Nitrification by Organized Ferments.**—Schlösing and Muntz conclude, from an extended series of observations, that the vegetable organisms of a low order, such as moulds and mycoderms, which lead to the slow combustion of organic matter, do not produce nitrification. On the contrary, they transform the nitric acid, at first, into organic matter; then, at least in part, into free nitrogen; the latter phenomenon being often accompanied with the production of ammonia. Consequently, they occasion a diminution of the combined nitrogen which exists upon the surface of the globe. When the nitrogen is present, under both forms, in a soil, the mycodermic vegetable which is developed there assimilates in the largest proportion the ammoniacal nitrogen.—*Comptes Rendus.* C.

**British Ceramics.**—In some complimentary remarks upon the British display of ceramics at the Paris Exposition, *Les Mondes* calls attention to "the brilliant specialties of the factory at Worcester, the English Sevres." The imitations of ivory are said to be so perfect as to deceive the eye, and require the testimony of the touch in order to detect the deception. Among the statuettes are some Chinese figures, which one would judge to be chiseled in ivory by the most skilful sculptor of the Celestial Empire. By their side are imitations of Japanese jade, with its semi-transparency, its elegant intaglios of flowers and birds, which are imitated to perfection. A little farther on are admirable representations of the old enamels of Limoges, with their lively painting, which are in white relief on a dark blue ground. In other places there are turquoises, which are embossed in relief, or ornaments of gold, so skilfully reproduced by means of the enamel, that one may well ask whether jewelry could do better. "It is evident to everyone that M. Binns, the present director of the Royal Factory at Worcester, has made a special study of Japanese art, and that he has introduced into its fabrication many of the ornamental suggestions created by the industrial artists of the extreme East." C.

**Spectrum of Gun Cotton.**—Vogel (*Annalen der Physik*, 1878, Bd. iii, S. 615) shows that the spectrum of exploding gun-cotton, which was observed by Lohse, is identical with the spectrum of calcium chloride. Numerous samples of pyroxylin, which were examined by Vogel, contained lime, which may have been easily introduced by the water employed in washing out the acids. C.

**Imperfections of the Telephone.**—Serpieri and Cappanera have studied the sounds which are only imperfectly transmitted by the telephone, and find a frequent confusion of the following sounds: *e, a; tr, cr, dr, pr, fr; n, m; s, f; et, el; eb, eu; d, t; ic, ip; dra, tra, gra; te, chi; at, ai; i, u; l, r; o, e; v, b.*—*Ding. Polyt. Jour.* C.

**Sonorousness of Alloys.**—Lilliman communicates a ringing elasticity to certain alloys of tin and other soft metals, with copper, antimony, etc., by plunging them for a short time in a bath of paraffine or oil, heated nearly to the boiling temperature. This operation, which produces a crystallization, slightly diminishes the density; it increases the hardness and rigidity.—*Pol. Notizbl.* C.

**A New Element.**—J. L. Soret, in following out some recent investigations of Marignac, finds conclusive evidence of the existence of terbine in gadolinite, although its existence has been doubted by Bahr and Bansen, as well as by Cléve and Hoglund. He also confirms Marignac's opinion that there is a fourth earth in the same mineral, resembling terbine in its yellow color, but having a smaller atomic weight. The ultra-violet spectrum of this fourth earth gives lines which have not been hitherto observed, and which are strongly indicative of a new element.—*Comptes Rendus.* C.

**Terrestrial Influence on Polarization of Light.**—In the course of his researches on rotary magnetic polarization, Henri Becquerel has been led to the direct estimate of the action of terrestrial magnetism upon different bodies. In the course of these experiments he has found that if a tube, containing bisulphide of carbon, is placed between a polarizer and an analyzer, in the plane of the magnetic meridian, there is an angular difference of 6·5′ between the two positions of the plane of polarization when looking towards the south or towards the north. This difference he attributes to terrestrial action.—*Comptes Rendus.* C.

**Cobalt Plating.**—Gaiffe had his attention called to the beauty and durability of cobalt, when deposited by the galvanic battery, and endeavored to utilize it as a substitute for iron and nickel, especially in electrotyping. It does not rust like iron, so that the surface can be easily preserved in good condition, and it is easily dissolved by weak acids, which do not attack the copper, whilst the nickel cannot be removed from a copper plate without injuring it. The beautiful whiteness of the cobalt makes it valuable for the decoration of other metals. He recommends a bath of a neutral solution of the double sulphate of cobalt and ammonia, which requires, in its preparation, about as much care as the nickel baths. The anode may be a leaf of platinum, or a plate of cast or forged cobalt. In order to obtain an adherent and white deposit, a current of about six units of electromotive force [Brit. Assoc.] should be employed at the beginning, and it should be reduced to about three units when the whole surface has become white. With a suitable intensity of current, the cobalt deposit is made nearly as rapidly as that of nickel. In four hours the coating may obtain the thickness of ·025 mm. If a very regular deposit is desired, the piece which is to be plated should be attached to the rheophore of the pile before plunging it in the bath.—*Comptes Rendus.* C.

**Luminous and Chromatic Sensations.**—Aug. Charpentier and Dr. Landolt have found that the sensations of light and of color are the results of two entirely distinct functions, which, although they are intimately blended in the habitual use of the vision, may be clearly distinguished from each other by physiological analysis. By experiments with lenses, they found that the sensibility of the eye to light was much greater when the eye is at rest in darkness than when it is in activity. There was, however, no such difference noticeable in the sensibility to color. Charpentier thinks that the explanation of this fact is to be found in the discovery by Boll and Rühne of a reddish chemical substance in the retina, which is discolored by light and which is renewed in darkness. If we admit, as seems probable, that the optic nerve is excited not directly, by light, but indirectly, by the chemical modification which the light produces in the retinal red, the superior sensibility of the eye in repose may be explained by the excess of the photo-chemical substance which the eye has acquired under the influence of darkness.—*Comptes Rendus.* C.

**Terrestrial Constants.**—J. B. Listing (Göttinger Gesellschaft der Wissenschaften) gives the following summary of the latest estimates of important geometric and dynamic constants: Major axis of the rotation ellipsoid, which most nearly represents the form of the earth, 6,377,377 metres; minor axis, 6,355,270 m.; radius of the earth, regarded as a sphere, 6,370,000 m.; length of the seconds pendulum at the equator, 0·9909948; ditto, lat. 45°, 0·9935721; ditto at pole, 0·9961495; g. at equator, 9·780728; ditto, lat. 45°, 9·806165; ditto at pole, 9·831603; centrifugal force at the Equator, due to the rotation of the earth, 0·0339117. C.

**Agricultural Use of Electricity.**—Berthelot commends Grandeau's remarks upon the "influence of atmospheric electricity upon the nutrition of plants," referring especially to his discovery that the proportion of nitrogenous matter, which is formed under that influence in tobacco and maize, is twice the proportion which is found in the same plants when withdrawn from the influence of atmospheric electricity; the total growth of the plant being proportional to the nitrogenous matter. He also calls attention to some of his own investigations, especially to the fact that free nitrogen is accumulated by organic matters, not only by employing the strong intermittent tensions of ordinary induction apparatus, but also with very feeble and continuous tensions, and especially by employing atmospheric electricity. In some of his experiments, microscopic vegetables appeared which absorbed an additional amount of nitrogen. Before his researches were undertaken, it was generally supposed that nitric and nitrous acids and their ammoniacal salts were produced only by the electricity of heavy thunder showers. It is now evident that the reactions between vegetables and the atmosphere, under feeble electric tensions, are the most important, the smallness of the effects being compensated by their duration, and by the extent of the surfaces influenced.—*Comptes Rendus.* C.

**A New Method for Cutting Rails of Uniform Length.**—Attention has been called by Dr. Kollman, of the Berlin School of Mines, to a method of photometric determination of temperature which is used in Russian rolling mills to ascertain the exact lengths into which rails must be cut when at a low red. Ordinarily the rails are allowed to cool down to a dull red, which is estimated, and are then cut by accurate mechanical means. It was found, however, that

their lengths varied considerably, because the temperature at which the rails had been cut differed, and therefore they did not contract evenly. If, however, the hot rails are looked at through colored glass, the color and tint may be so chosen that when the rail has arrived at a certain temperature it becomes invisible to the eye, this being the time when it is to be cut. Blue or orange glass is best adapted for this purpose. In order to obtain good results, the observations should always be made from the same distance.—*Metallurgical Review.*

**The Phonograph Diaphragm.**—Dr. Clarence Blake, of Boston, in his experiments with the phonograph, was led to believe that a diaphragm, shaped like the drum membrane of the human ear, might give improved phonographic utterance. He arrived at this conclusion from finding that flat disks gave too great a prominence to certain heavier overtones of the voice to which they respond, and hence falsified the *timbre* of the voice in reproducing it. By forming the phonograph diaphragm into a flat trumpet-shape (with a funnel section) and fixing the embossing style into the cusp, it was found that the lighter overtones were faithfully reproduced by it, while the sharper exaggerated overtones recorded by the flat disk were cut off. When the embossing, as well as the reproducing, was done by this curved membrane, the sharper overtones disappeared, and the quality of the voice was much more natural. Moreover, there was a gain in sensitiveness; the embossing could be done at a distance of 15 feet from the speaker, and clearly reproduced. The material of these membranes may be either stout felted paper, varnished on its outer surface, or drum-vellum, moistened and modeled into shape before using. "The principle governing the vibrations of such a disk," says Dr. Blake, "is that of imparting the vibrations to the centre of a membrane, the curve of which enables it to reproduce a large range of overtones, its tension serving as a counter-balance to the central pressure." Dr. Blake has also found that the groove in the phonograph cylinder, when covered with tinfoil, became a resonator for the high scratching noise of the embossing point, and materially interfered with the reproduction of the quality of the voice. By stretching a thin layer of rubber tissue over the cylinder, this resonating effect was abolished, and the scratching noise materially lessened. —*Telegraphic Journal.*

**Stethoscopic Microphone.**—M. Ducretet, says the *Telegraphic Journal*, has applied the pneumatic tube vibration-transmitter employed by M. Marey in physiological experiments, to the microphone. This consists of a flexible india-rubber pipe connecting two small drums, or closed air-chambers with convex lens-shaped membranes, so that when one of the membranes is pressed against the pulse, the other membrane will pulsate the air-transmitted air-vibrations. M. Ducretet makes use of it by resting one of the lens-shaped membranes upon the upper contact of a pencil microphone, leaving the other drum free to be applied to the pulse, the lungs, heart, or other organ of the body. This has been called the *stethoscopic* microphone.

An arrangement similar to this was exhibited at the meeting of the Franklin Institute, on June 19th last, by Mr. A. E. Outerbridge, but with the advantage of the microphone being attached direct to one of the membranes. *

**Discovery of the Planet Vulcan.**—Prof. J. C. Watson, of Ann Arbor, under date of August 2d last, sends to Rear Admiral Rogers, Supt. of the Naval Observatory, the following report of his observations during the total eclipse of the sun, on July 29th, of what he believes to be the long talked of planet between Mercury and the Sun:

"I have the honor to report that at the time of totality, I observed a star of the four-and-a-half magnitude, in right ascension, 8 hours, 26 minutes declination, 18 degrees north, which is, I feel convinced, an intra-mercurial planet. I observed with a power of forty-five, and did not have time to change the power so as to enlarge the disk. There is no known star in the position observed, and I did not see any elongation such as ought to exist in the case of a comet very near the sun. I will hereafter report to you more fully in regard to the observations made. The appearance of the object observed, was that of a ruddy star of the four-and-a-half magnitude. The method which I adopted prevents the possibility of error from wrong circle readings; besides, I had memorized the Washington chart of the region, and no such star was marked thereon. By comparison with the neighboring stars on Argelander's scale, the magnitude of the planet would be fifth, although my direct estimate at the time of the observation was four-and-a-half, as stated." *

**Temperature of Flames.**—Signor F. Rosetti has made the temperature of flames the subject of a series of investigations. For this purpose he has made use of the calorimeter of his own invention. The maximum temperature of a Bunsen flame he has found to be 1360° Cent., obtained by the combustion of one volume of gas and two and one-fifth volumes of air. The admission of either a greater or less quantity of air reduces the temperature. Changes in pressure have but slight influence on the temperature. The flame given by gas diluted with its own volume of nitrogen shows a temperature of 1180°, and diluted with three volumes of nitrogen, 1040°. The same degrees of dilution with carbonic acid show, respectively, 1100° and 780°. Among other temperatures noted were the following: From Locatelli lamp, 920°; stearine candle, 940°; petroleum lamp with chimney, 1030°; the same without chimney, illuminating part, 920°; sooty envelope, 780°; alcohol lamp—alcohol, 0·912—1170°; ditto—alcohol, 0·822—1180°. The difference in the heating power of alcohol resulting from widely-differing percentages of water is considerable.—*The Engineer.*

**The Tasimeter and Magnetization.**—Professors Andrew and Thomas Gray have published, in *Nature*, an account of their experiments to detect, by the use of Edison's tasimeter, the elongation and shortening produced, in a bar of iron, by magnetization and demagnetization.

A piece of stout iron-wire was placed in the instrument, in the usual manner, and surrounded by a helix, through which a battery current could be passed.

The terminal wires from the plates bearing on the carbon bottom, were joined in circuit with one Daniell's cell and a Wheatstone bridge, in which a delicate Thomson's reflecting galvanometer was employed. The pressure of the iron rod against the carbon bottom, and the resistances, were so adjusted that the galvanometer pointed to zero.

Upon passing the current from one Daniell's cell through the helix, the galvanometer needle was considerably deflected, but returned to zero when the current was broken, showing that the iron core had been lengthened by magnetization.

By replacing the comparatively rough adjusting screw of the tasimeter by a micrometer screw, they hope to determine the exact amount of elongation or shortening produced, in a piece of soft iron or steel, by given changes of magnetic intensity.

## THE TELEPHONE RELAY.

*Editors* JOURNAL OF THE FRANKLIN INSTITUTE:

Sirs:—Since the publication, in the JOURNAL OF THE FRANKLIN INSTITUTE, vol. cvi, 1878, of a short article on the Microphone Relay, by Prof. Thomson and myself, I have noticed two claimants for priority of invention; one in the *Telegraphic Journal* of London, of July 1st, and the other in the *Chemical News*, of July 26th.

The writer in the *Telegraphic Journal*, after briefly commenting on the claim of Prof. Thomson and myself, to the invention of the Microphone Relay, as contained in a short note to *Nature*, of June 20th, remarks as follows: "This application was pointed out, as we reported in our last number, by Prof. Hughes, at a meeting of the Physical Society, on June 17th." The writer could scarcely have given careful attention to our note to *Nature*, or he would have seen that it was dated Philadelphia, June 7th, and therefore clearly anticipated the application pointed out by Prof. Hughes, on June 17th. As you are aware, we exhibited a successful working model of our relay at the Institute and elsewhere, on June 4th, accounts of which were published in the papers of this city on the following day.

The writer in the *Chemical News*, of July 26th, is Mr. Edison, of New Jersey, who claims priority of invention by more than a whole year. Though I have been informed by others that Mr. Edison made this claim, yet, so far as I am aware, this is the first time the gentleman has made the claim over his signature, and I therefore take the present opportunity of answering it. In his letter to the *Chemical News*, Mr. Edison employs the following unequivocal language, viz.: "Allow me to state that *the telephonic repeater described by Messrs. Houston and Thomson* in your issue of June 21st, was invented by me over a year ago, and *one of the many* forms devised by me was published in the *Journal of the Telegraph*, July 15th, 1877, and in the *Telegraphic Journal*, of London, about the same date." (The italics are my own.) Here it would appear that Mr. Edison claims the particular form of repeater described by Prof. Thomson and myself. Now, whatever Mr. Edison may have accomplished in this direction prior to the announcement of our invention, he can only claim what he has published. It will not do for him to claim many (any) forms. In his letter, he alludes to but one, viz.: that published in the *Telegraphic Journal*, of July 1st, 1877. I have carefully read his article, and find it to be a description of a "Pressure relay" for his speaking telegraph. This speaking telegraph, so far as I have been able to ascertain, *is not a telephone*, but a species of harmonic telegraph, similar to that of Gray, and the invention was for the purpose of repeating the vibratory pulses employed in

that system. Mr. Edison nowhere, that I can find, claims, prior to our announcement, that this relay was applicable to the *articulating telephone*, and it would appear very improbable that had he been aware of the fact, he would have failed to have given it publication. It would seem to me that since the invention of Prof. Thomson and myself consists in an application of Prof. Hughes' microphone to the Bell articulating telephone, that before Mr. Edison can establish his claim to our telephone relay, he must substantiate his claim to the invention of the microphone, and this, it would appear, he has as yet failed to do. Respectfully Yours,

EDWIN J. HOUSTON.

CENTRAL HIGH SCHOOL,
*Phila., August 22d*, 1878.

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## Book Notices.

REPORTS AND AWARDS OF THE INTERNATIONAL EXHIBITION, 1876. Group XX, Motors, Hydraulic and Pneumatic Apparatus, &c., 8vo, pp. 424. Price, $2.00. J. B. Lippincott & Co.

The exhibits embraced in the group are mostly such as the members of the Institute are largely interested in, and considerable space has been devoted to their discussion in the JOURNAL, and, therefore, the report may be allowed more than usual attention.

While great weight may be placed upon the opinions of the judges, based upon a mere examination of the various exhibits, together with their past experience; yet in such a group as this, by far the most valuable information is to be derived from careful and scientifically conducted tests. In this instance, such tests of the steam boilers, water-wheels and steam fire-engines were instituted, and thoroughly carried out by experts, especially fitted for the work.

The method employed and the manner of conducting the boiler tests, together with a table of the more important results, have already been given in the JOURNAL,[1] and, therefore, need not be expected here. In addition to this, the general report contains an article by Mr. Charles E. Emery, one of the judges upon "Boiler Proportions," in which he says: "The experiments do not indicate that mere peculiarty of arrangement of mechanical details affects, to any material degree, the comparative efficiency of boilers. * * * *

[1] See vol. civ, page 105.

"It is believed that a boiler with any kind of mechanical details and arrangements, not absolutely faulty, can be proportioned to give the same evaporative efficiency as one of any other form."

Diagrams are given comparing graphically the results of the Centennial boiler tests with each other, and also with those obtained by other experimenters, notably those of Chief Engineer B. F. Isherwood, United States Navy, during the years 1858 to 1866.

These diagrams also throw additional light on the question as to how far mere evaporative economy should control the size of boilers for a desired service, and the writer very properly says: "The conditions of each particular case must determine the question whether a saving of fuel, with increased first cost, is of greater importance than an original saving in cost of construction, * * * * first cost can be increased till the saving in fuel equals the interest." * *

Both these views have been widely, if not generally, adopted by engineers, but this additional evidence of their truth is very acceptable.

The committee on boiler tests state, however, "that the award of the judges were not based upon the trials; in fact the latter were not commenced until the awards had been made by another committee of the same group."

The exhibits of turbine water-wheels were very numerous. The report of Mr. Samuel Webber, superintending engineer of Centennial turbine tests, together with records and drawings of the various wheels tested, is given, but without comment by the judges, except a few commendatory remarks by Mr W. H. Barlow, on page 122, taken from the report of the British Commissioner. This was also reviewed in the JOURNAL, from advance sheets of the Report of the Chief of the Bureau of Machinery, rendering further notice here unnecessary.

Considerable attention was given to comparative trials of steam fire-engines, and the results, as given in detail, possess much interest. In this case, as in that of the water-wheels, there is no analysis of the tabulated results, which certainly is desirable, and would have added greatly to the value of the experiments.

The trial of the Hoadley portable steam engine, recorded on pages 152–8, shows results seldom, if ever, equaled by engines of that class.[1]

There was little of novelty among the exhibits of stationary steam engines, and that part of the general report devoted to them is limited to a mere description of the more prominent ones. There is an article, by Chas. E. Emery, on "Steam Engine Economy," based,

[1] In the course of his preparations for these tests, Mr. Hoadley made other experiments, a portion of which appear in the following valuable papers, published in the JOURNAL: "Radiation from Steam Boilers," vol. ciii, page 233, and "The Curve of Compression," vol. cv, page 1.

however, entirely upon the performance of engines other than those on exhibition.

An outline is given of the "American" system of transmission of power, including the substitution of belting for large gear-wheels between the motor and the lines of shafting, and also the American shafting, as introduced, by Messrs. Wm. Sellers & Co., twenty years ago, and now generally adopted in this country. As an example of the extent to which belt transmission is employed here, mention is made of a leather belt on exhibition, made to order, which is 5 ft. wide, 186½ ft. long, and weighing 2212 lbs., the largest belt ever constructed.

There was a large display of hydraulic exhibits, although presenting few novel features. The article on "Pumping Engines" contains a comparison of the performance of some of the well-known designs, and a short historical sketch of the progress of improvement of this class of machines in the United States.

Under the head of "Steam Boiler Inspection," there is given an interesting account of the workings of the Manchester (England) Steam Users' Association, by Mr. L. E. Fletcher, the Chief Engineer, and which is worthy of the attention of steam users everywhere. *

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OUTLINES OF NATURAL PHILOSOPHY. By Prof. E. J. Houston. 12mo, pp. 123. Philadelphia; Claxton, Remsen & Haffelfinger. 1878.

This little book is intended especially for young children, and the author has been at great pains to bring the elementary principles of natural philosophy within their comprehension, by the use of simple language, in explaining things common to the experience of every-day life.

Children often acquire false notions of natural laws, by attempts to teach them things beyond their powers to grasp, and to prevent this there is a wise omission of all topics which, from their nature, do not admit of a thorough explanation in language adapted to those for whom the book is designed.

Evidently aware of the importance of enlisting the sympathies of children in their studies, Prof. Houston has, to a large extent, drawn his illustrations from things connected with their pleasures, thus forming an association of ideas more likely to be lasting.

The book is in the usual style, of question and answer following each other in a natural and easy sequence.

The eagerness with which it was read by several boys of suitable ages, into whose hands it accidentally fell, proved its adaptability to their wants. *

## MEMOIR OF B. H. MOORE.

Bloomfield Haines Moore was born in the City of Philadelphia, December 16th, 1819.

His parents, Samuel French Moore and Rachel Matlack Moore (whose maiden name was Haines), were members of the religious Society of Friends, and were natives of New Jersey.

The paternal ancestor of the fifth preceding generation, John Moore, emigrated from his home in Lincolnshire, Eng., in 1677. His family was a branch of the Devonshire Moores, now extinct in England.

The Harvard class history of the son of Mr. Bloomfield H. Moore, mentions the fact that the family bible, brought from England by one of his paternal ancestors, is of the edition of 1616, printed in London; and that the family bible of his mother's family is "the Geneva version of 1599, much valued on account of its notes." Both of these ancestors belonged to the Society of Friends, and left England on account of religious persecution, following William Penn to this country, after first sending a commissioner, who purchased tracts of land (for them and their connections) in New Jersey, Pennsylvania, and Massachusetts.

During the latter part of the last century, the descendants of John and Benjamin Moore were notified, first by advertisements in Trenton and Philadelphia newspapers, and afterwards by letters from a solicitor in London, that they were heirs to an estate in England, amounting to some millions of pounds sterling. The answer, sent back by Joseph Moore, who represented the family on this occasion, was that they had enough of this world's goods, and were contented with their situation in life. As this property was left to them by a will registered in Doctors' Commons in London, an effort was made, early in this century, by one of the descendants, to recover the estate, but, as the house of Joseph Moore had been burned in the meantime, with all its contents, including the family papers, the attempt was abandoned, as involving too much expense.

The descendants of John Moore, in western New Jersey, were large landed proprietors, and lived upon their property down to the time of Mr. B. H. Moore's grandfather, Amasa Moore, who married Agnes French. Bethuel Moore, the father of Amasa, survived his son twenty-one years, and, although the wealthiest man in Burlington County, he had the good sense to choose trades for his orphan grandchildren, the three sons of Amasa Moore. It was he, also,

who furnished the capital with which they went into business for themselves, after they had learned their trades. He died March 4th, 1831, aged 89.

A friend of the family, the late Jacob Ridgway, befriended the young architects and builders, and did all that was in his power to throw business into their hands.

Samuel French Moore, the father of the subject of this sketch, and grandson of Bethuel Moore, was a man of such marked ability, that Mr. Ridgway encouraged him to go into the real estate business. Success attended whatever he touched, but he died at the early age of 30, leaving his two children to the guardianship of Mr. Ridgway, who also administered their father's estate.

Mr. Samuel F. Moore's widow continued to reside in the house built for her by her husband, until her death, which took place May 19th, 1851. The house, which is still owned by her son, Carlton Ridgway Moore, now living in Virginia, is situated on Carlton Square, in a street named after Lady Callowhill, a relative of William Penn. Carlton Square was in a pleasant suburb of our city (surrounded, as it was, by old country seats) at the time the site was chosen by a small colony of Quaker families; but at the present time this street is principally occupied by shops and dwellings of an inferior character, with the exception of this one block of now venerable houses in Carlton Square, and the newer residences opposite.

The maternal ancestor of Mr. Moore, Richard Haynes, after his imprisonment in England for being a Quaker, emigrated to America, to escape religious persecution. The homestead, for which a patent was granted at Evesham, N. J., in 1683, is still in possession of the Haines family, who have changed the *y* into an *i* in their name. George Haines, who died at the age of 79, April 13th, 1877, was one of the oldest physicians in New Jersey. He was the brother of Mr. Moore's mother.

The early education of Mr. Moore was conducted at the well-known Friends' School of Isaac Taylor and Thomas Conrad, where he was prepared for passing examination at Princeton College, according to the wish of his father; but objections being raised by a member of the family of his guardian, and a course of study at Clermont Academy[1] advised, the sons of Samuel French Moore finished their

[1] Formerly a Military School.

school education at this academy, which bore a high reputation in its day.

Bloomfield H. Moore then entered the office of Mr. Ridgway, in which he remained until he went into business for himself. In October, 1842, Mr. Moore was married to Clara, only daughter of Augustus E. Jessup, of Western Massachusetts; and in 1843, Mr. Moore gave up the business in which he had invested a legacy of $10,000, left to him by his guardian, and entered into partnership with his father-in-law, Augustus E. Jessup, under the firm name of Jessup & Moore, dealing in paper and paper stock.

In 1845, the firm of Jessup & Moore enlarged their business by commencing the manufacture of paper on the Brandywine. Mr. Jessup, as a scientist, had, many years before, made experiments for improving the manufacture of paper, and in consequence of his success in these experiments, he had established his well-known paper-mill in Westfield, Mass., where he made bank-note paper, holding large contracts with the United States Government for its manufacture. This mill he disposed of to his brothers when he removed to Philadelphia. Mr. Moore invested in this (to him) new business (the manufacture of paper), not only the profits of his previous business, but also the money that he inherited from his great-grandfather and his father. In addition to the united capital of the firm, Mr. Alfred Dupont, the classmate and life-long friend of Mr. Jessup, advanced nearly fifty thousand dollars for enlarging the business, refusing to take from Mr. Jessup any mortgage, note, bond, or evidence of debt whatever, from the time of lending the money to the time of its return.

The original paper-mill of Messrs. Jessup & Moore, now known as the Augustine Mill, has since been greatly enlarged by Mr. Moore, and is probably not excelled by any in the world for perfect adaptation to the work. Subsequently the firm erected paper-mills at Rockland and near Coatesville, and have, for years, been the largest manufacturers of paper in this country.

Although actively engaged in a business which required close attention, rendered the more necessary by its rapid development, Mr. Moore found time for reading and for pursuits which were congenial to his taste, and for the accumulation of a very valuable library. Political economy and social science were branches to which he devoted considerable attention; several monographs from his pen were published on occasions of public interest.

Mr. Moore became a member of the Franklin Institute in March, 1863, and was elected to its Board of Managers in 1864, and served as a manager until 1877.

In 1869, he was elected one of the vice-presidents of the Institute, and served eight years. From 1864 to 1874, he was one of the curators; and from 1867 to 1877, a member of the Committee on Publication, and during most of the time was chairman of the committee. For ten years he served on the Committee on the Library, and for nine years on the Committee on Exhibition. At the close of the year 1876, his family urging some relief for him from engagements outside of his business, he declined re-election to any official position in the Institute.

Mr. Moore died at his residence, South Broad Street, Philadelphia, July 5th, 1878, from acute pneumonia, which supervened an attack of pleurisy. His illness was of one week only.

Endowed by nature with a well-balanced mind, Mr. Moore was well calculated for the successful prosecution of whatever he undertook. Careful, without unnecessary timidity, he was always ready to appreciate and take advantage of whatever tended to advance manufacturing skill in his department.

In his business relations he was affable, obliging, just, and careful to avoid offense; possessing qualities valued in social intercourse, he was an intelligent and agreeable companion, and he leaves a large circle of friends, who unite with his family in mourning his loss while in the meridian of his strength and usefulness.

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## Franklin Institute.

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